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PROCEEDINGS
OF THE
CONFERENCE ON

# SECURING INSTALLATIONS AGAINST CAR-BOMB ATTACK

ARLINGTON, VIRGINIA
MAY 15-17, 1986



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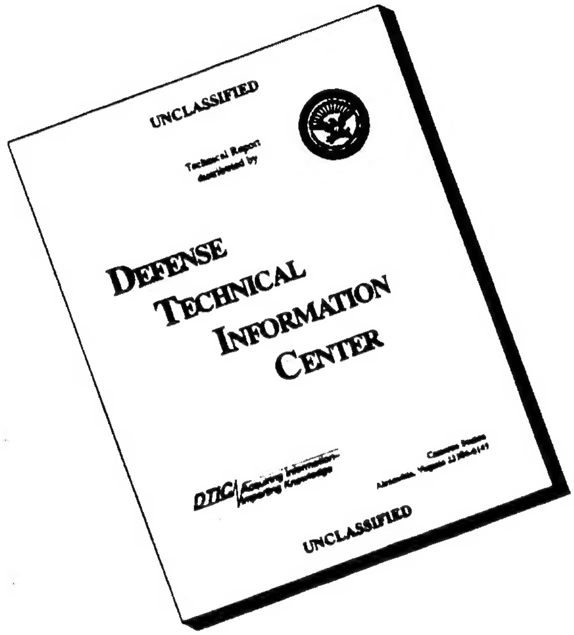


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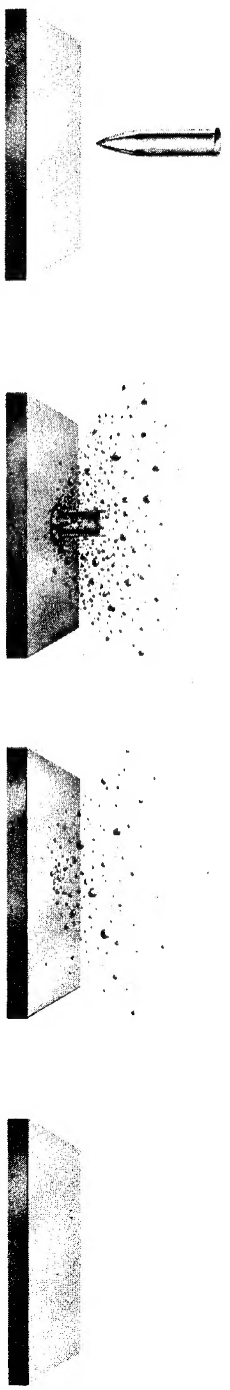

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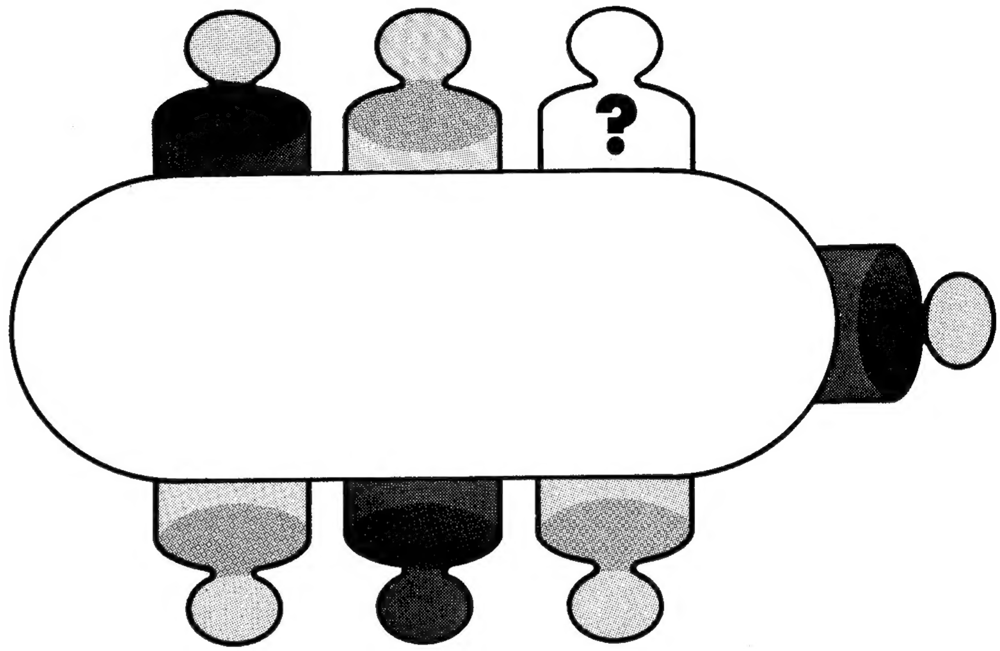

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VOLUME III

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## VEHICLE BARRIER ENGINEERING DESIGN

# THE ASP WALLING SYSTEM

## The proven blast and fragment resistant system for protective structures

Presentation on 17 May 1986
to
DRI Seminar

by

Yaakov Yerushalmi
James A. Johnson

## ABSTRACT

A description with sketches is given of the blast and fragment resistant ASP walling system, which consists of formed metal sheets joined together to constitute both the permanent formwork and the reinforcement to the concrete, which is poured into the voids between the sheets. Tests are described and results outlined which were carried out with a 1000 and 2000 lbs GP air bombs, RPG7, 68 mm aircraft rockets, explosive charges and mines. All tests results were successful within the design criteria. A static flexural test is also described.

## 1. SYSTEM DESCRIPTION

The patented blast and fragment resistant ASP walling system is a composite construction of steel and concrete, designed to provide protection against weapon effects in a more cost effective manner than does conventional reinforced concrete designed for protection.

The basic component of the ASP system is a wall element shown in Figure 1, consisting of interlocked external sheets. The two faces are tied to each other by diagonal panels shown in Figure 2 which, in zig-zag fashion, form the lattice-work of a rigid mould into which concrete is poured.

The sheets, which are presently available in three thicknesses, 0,8 , 1,0 and 1,2 mm, provide the necessary reinforcement to the concrete. The sheets are presently rolled in three modules : 200 mm, 250 mm and 300 mm thick walls. The standard sheet profile is shown in Figure 3.

The sheets are pre-cut to detailed lengths, marked and delivered to the site.

After conventional concrete foundations have been cast with starting reinforcing bars to project and tie into the walls, the sheets are erected and lined-up against a kicker angle fixed to the footing.

The external sheets easily interlock into each other at their shaped ribs in male-female fashion as shown in Figure 4. The sheets in the two external faces are staggered so that the ribs may receive the lacing panels. These lacing panels are slid in from the top and secured with self-tapping screws. The assembled sheets form a rigid mould ready to receive the concrete. The lacing panels are perforated with circular holes to allow the flow of the fresh concrete through them.

The external sheets form the main reinforcement to the concrete. They provide the section with symmetrical tensile and compressive reinforcement. The lacing panels form a lattice-work properly securing the external faces to each other, and also act as a uniformly distributed shear reinforcement.

The only reinforcement bars that are necessary in the walls are the starter bars from the foundation into the

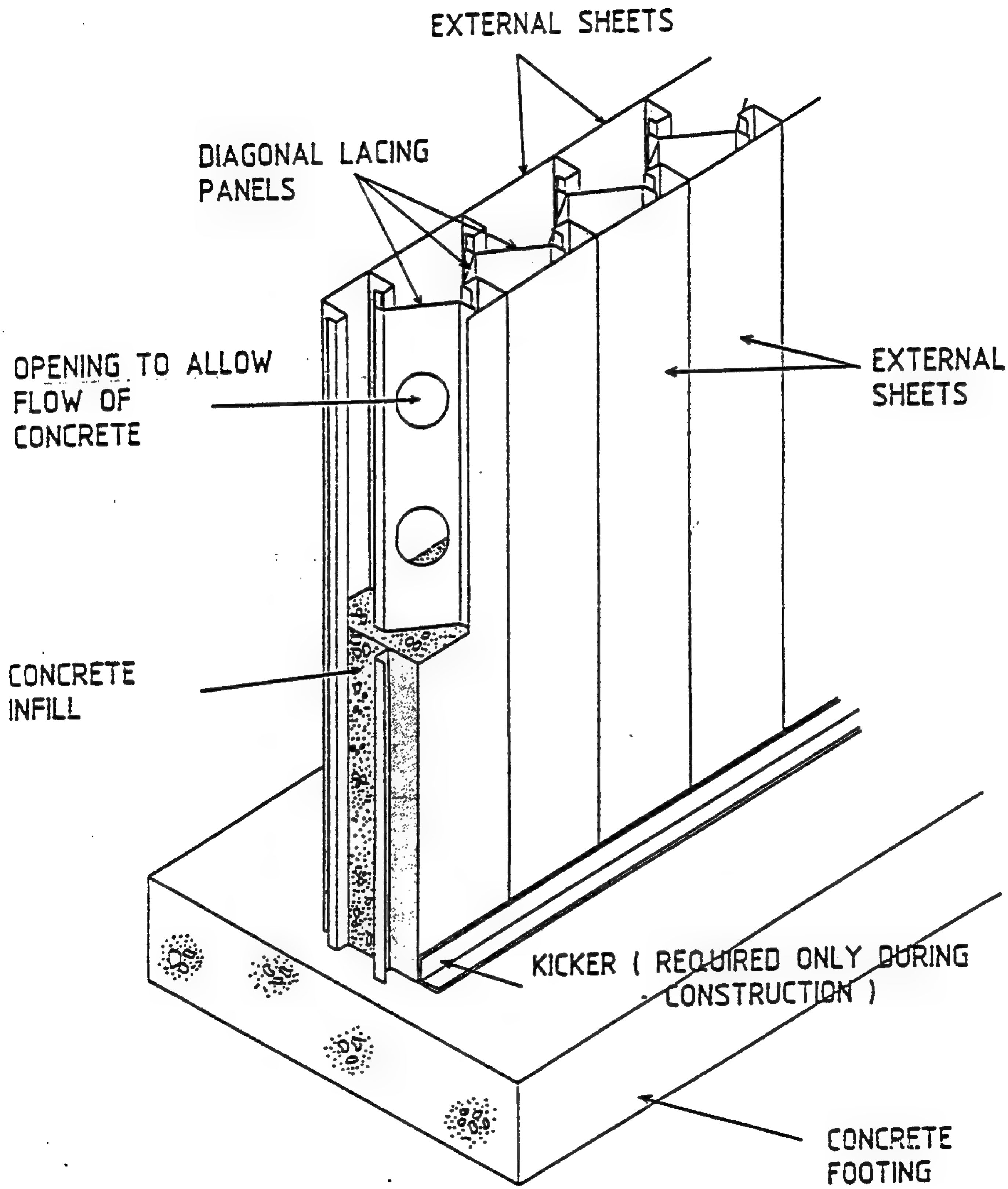


Figure 1.

THE ASP WALLING SYSTEM

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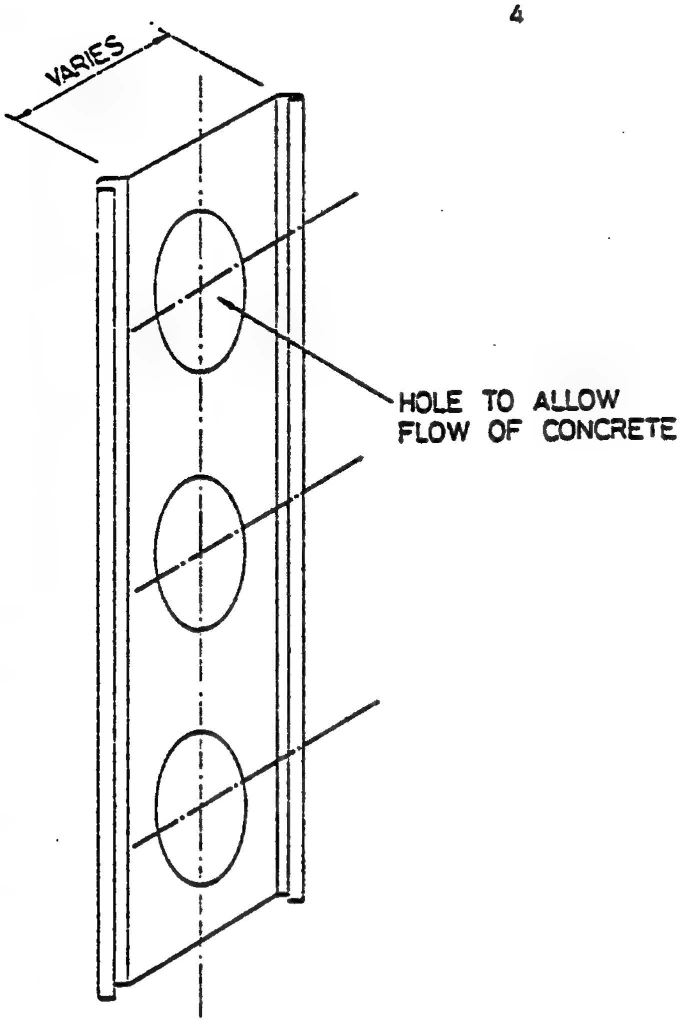


Figure 2.
Lacing Panel.

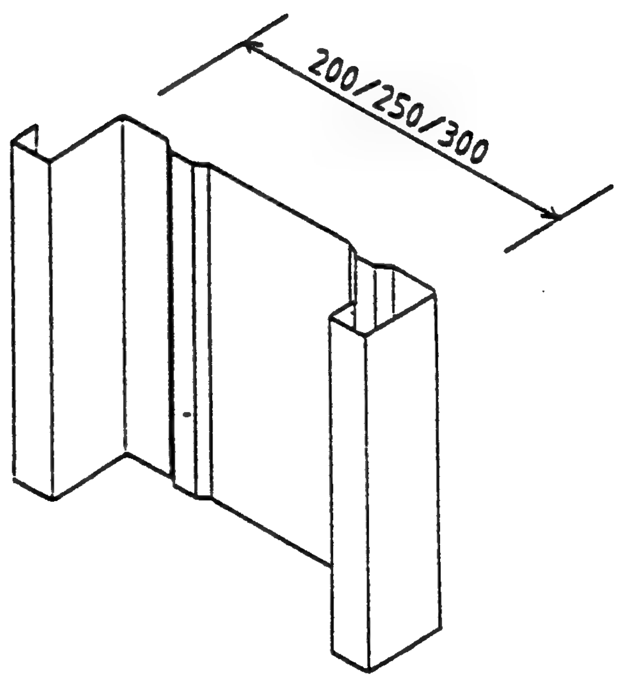


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Figure 3.
Standard Sheet Profile.

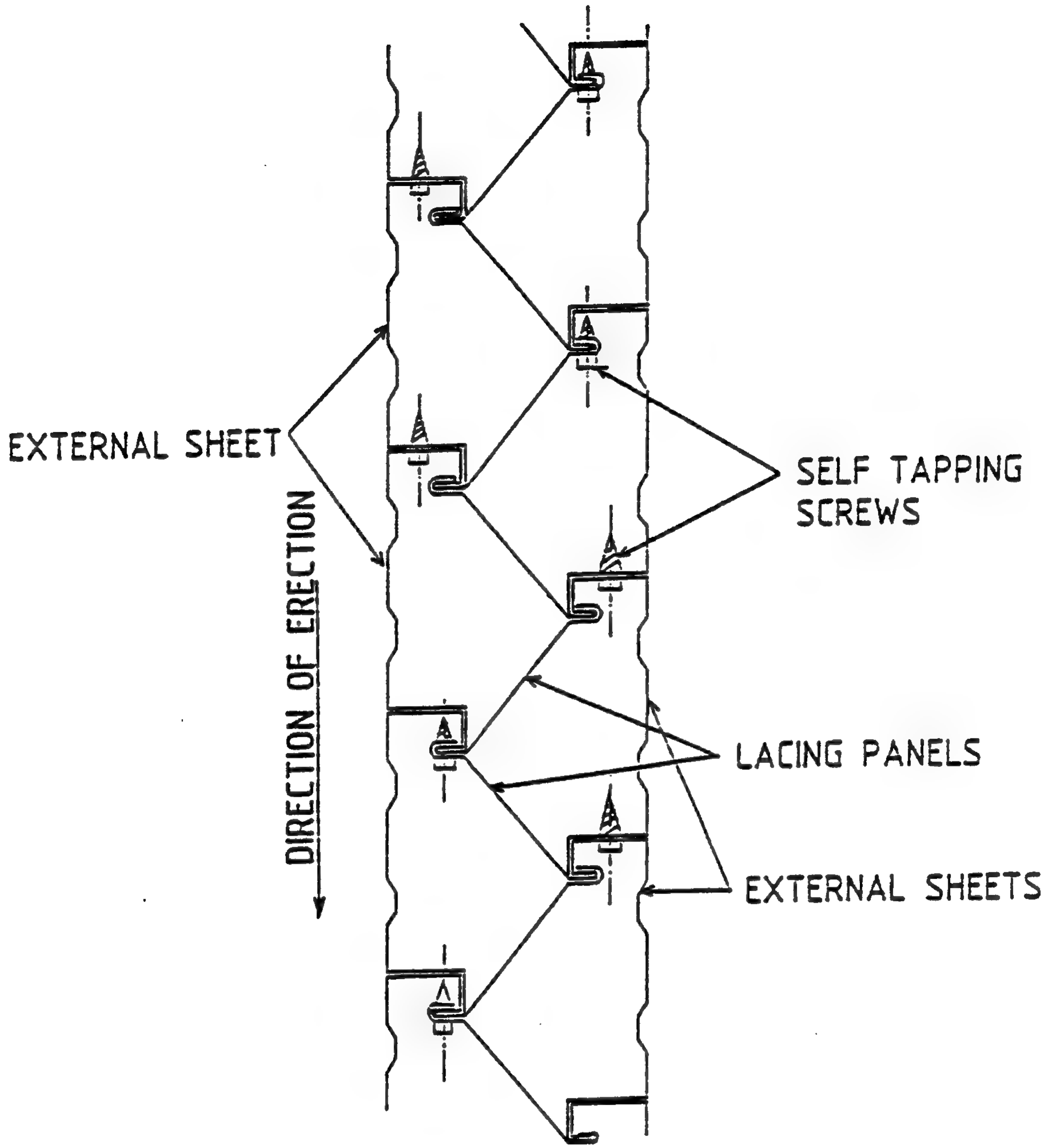



Figure 4.

Assembled Sheets.

walls, and corner bars at a connection between a wall and a roof slab.

Into the rigid steel mould which has been assembled a pumpable 4500psi (30MPa) concrete mix, with slump between 100 and 150 mm is placed to complete the construction of the walling system.

The system produces a strong, ductile and fragment resistant component for the construction of protective walls and hardened buildings. The sheeting forms a natural anti-spalling plate which is not available in conventional reinforced concrete walls.

A sandwich type construction has also been developed consisting of two walls 400 mm apart, with the void being filled with crushed stones usually 40 to 80 mm in size, as shown in Figure 5.

The walling system has been put to the following uses :

- protective walls up to 10 m high;
- above ground buildings to resist weapon effects;
- ammunition storage magazines;
- chambers to resist effects of internal explosions ranging from 4 to 500 lbs;
- general protective walling systems to protect against attacks ranging from purely intrusion and bullets, to direct hits from RPG7 rockets, light artillery of the 122 mm type, mortars and general purpose aerial bombs.

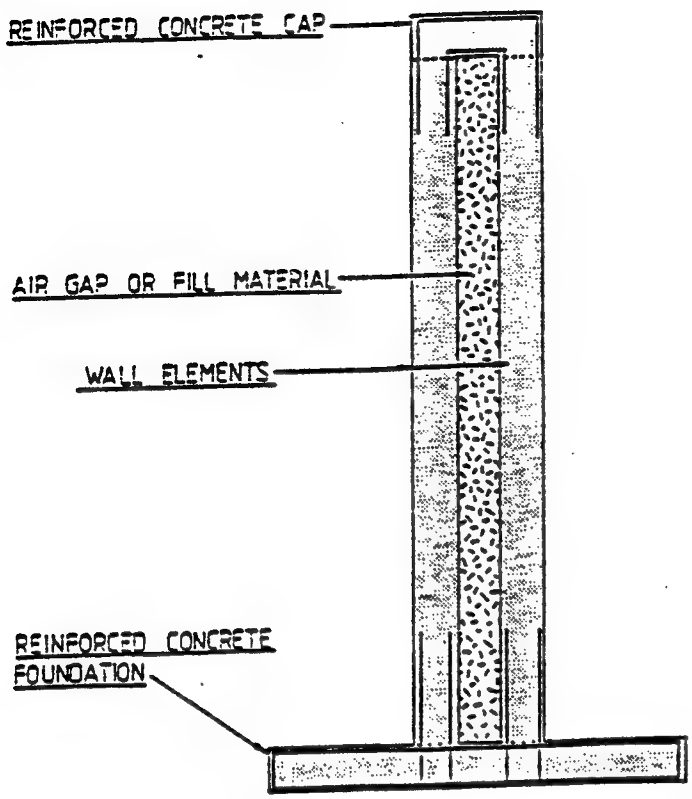



Figure 5.

Sandwich Construction.

Figure 6.
1000 lbs Test.

## 2. SYSTEM TESTS AND RESULTS

### 2.1 1000 lbs GP air bomb at 10 m distance

The sample tested for the above criterion was a 250 mm thick, 2 m high ASP wall used to form a 2 m long x 1,5 m wide cubicle.

The test sample was placed with the large face being 10 m away from the centreline of the bomb which was laid on a wooden trestle 1,5 m above the ground. After detonation of the bomb, the following results were observed (see Figure 6).

A number of large craters up to 250 mm in diameter were observed having penetrated the first sheet and the concrete to a maximum depth of 40 mm. There were a multitude of small hits with no penetration. The back plate of the wall resisted any spalling and showed absolutely no signs of any damage or deflection. Damage to the first face was local, with no propagation of cracks. A bikini gauge placed on the inside face of the front wall did not register any blast effects.

### 2.2 2000 lbs GP air bomb at 10 m distance

After the successful performance of the ASP wall element in the above test, samples were tested against a 2000 lbs weapon.

Two samples were tested against two detonations as follows :

- sample 'A' :

  this sample was the same sample used in the 1000 lbs test. For the first detonation, the sample was placed with one of its untouched small sides facing the weapon at 10 m distance, close to the centreline of the weapon.

  For the second detonation, the sample was placed with its untouched large side facing the weapon at 10 m distance from the centreline of the bomb.

- sample 'B' :

  this sample was a cubicle made out of 200 mm thick ASP wall element. The cubicle was 2 m high x

3 m long x 1 m wide. This provided with a front and a rear 2 m x 3 m face suitable for testing, each supported on their four sides.

For the first detonation, the sample was placed 15 m away from the bomb, at $45^o$ from the weapon centreline.

For the second detonation, the sample was turned at $180^o$ to present its second face opposite the weapon and was placed 10 m away at about $15^o$ from the weapon centreline.

The following results were observed :

- sample 'A' was hit by both detonations while sample 'B' was only significantly hit by the second detonation;
- a number of large craters up to 250 mm in diameter were observed on both samples having penetrated the first sheet and the concrete to a maximum depth of 100 mm. One large fragment almost penetrated the full thickness of the 200 mm thick sample;
- no perforation took place and the back steel sheets resisted any spalling;
- rear face deflections were localized with a 20 mm bulge noticed behind a large crater in the 250 mm thick sample and a 50 mm bulge behind the large fragment that hit the 200 mm thick sample;
- damages to the front faces were localized with craters not exceeding one sheet width and with no crack propagation in the concrete.

## 2.3 Direct hits of RPG7

The sample tested for the above criterion was a sandwich section consisting of a 200 mm ASP wall, a 400 mm gap filled with granite stones of 40 mm size and a rear 200 mm ASP wall (see Figure 7).

Several RPG7 rockets were fired at the sample from a distance of 100 m.

All the rockets that struck the target, penetrated the outer 200 mm ASP wall, the 400 mm granite stones

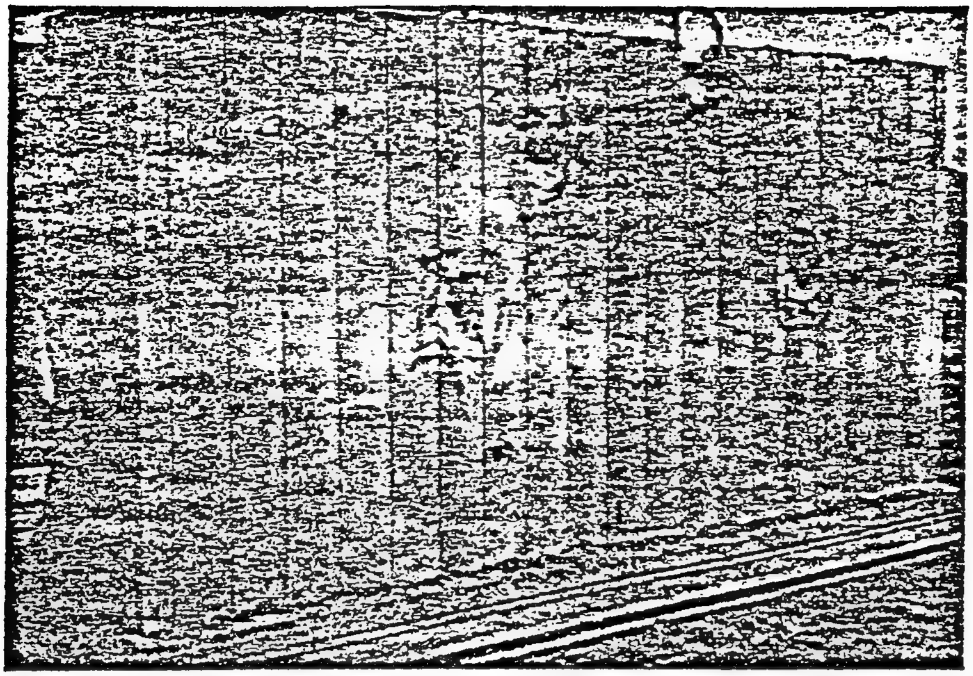


Figure 7.
RPG7 Tests.

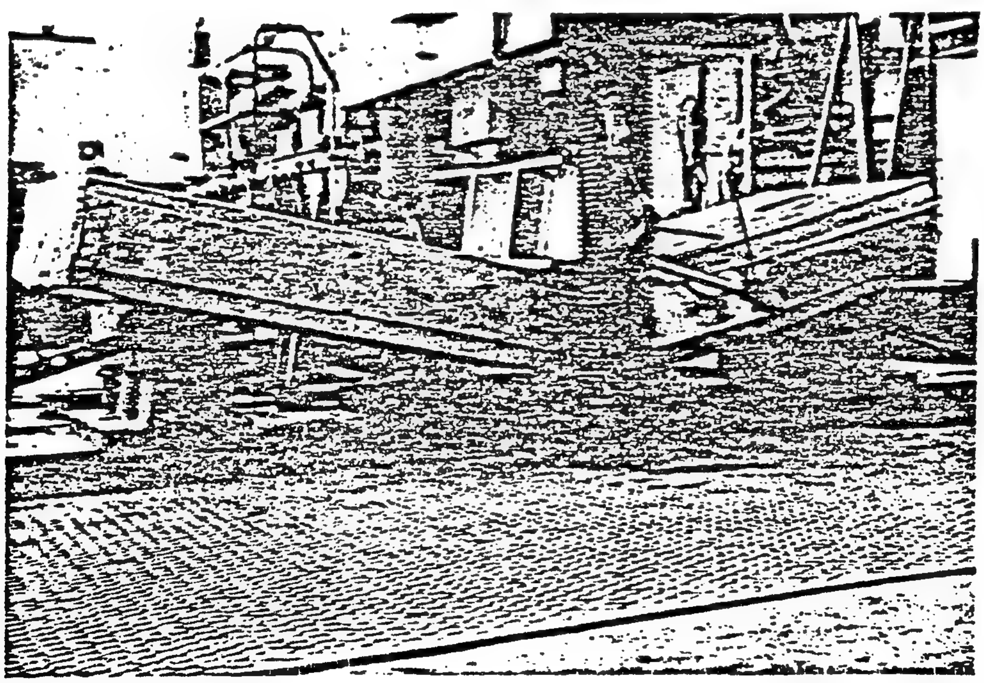


Figure 8.

Static Flexural Test.

and about half of the inner 200 mm BFR wall, causing a heavy local plastic deformation on the exterior face of the second ASP wall. The rear metal skin of the wall prevented any spalling of the concrete.

2.4 Direct hits of 68 mm aircraft rocket

The sample tested for the above criterion was a sandwich section consisting of 200 mm ASP wall, a 200 mm gap filled with granite stones of 40 mm size and a rear 200 mm ASP wall.

Rockets were fired at the sample and two direct hits were registered.

The damage to the sample was localized to the vicinity of the hits, with the exterior metal skin being removed by the blast, and the exposed concrete pitted to a depth of 20 to 30 mm. There was no other damage to the sample, and no evidence of bulging or breaching on the back face. The exposed concrete was in no way cracked.

Since only the first leaf of the sample was damaged it can be inferred that a single 200 mm ASP wall will supply 100% protection against this rocket.

2.5 Placed explosive charges and mines

The ASP walls were also tested against placed explosive charges. The following was observed :

- 1,7 kg PE4 plastic explosive shaped charge does breach a 200 mm thick ASP wall with a localized opening about 400 mm x 500 mm. Damage is very local;

- 1 kg PE4 plastic explosive does crater a 200 mm thick ASP wall (200 mm x 400 mm crater) but does not penetrate the wall;

- 1,7 kg PE4 plastic explosive shaped charge does crater a 300 mm thick ASP wall but does not penetrate the wall. The crater is about 300 mm in diameter and 80 mm deep. The back skin of the tested wall was bulged outwards by about 30 mm over an area of 0,5 $m^2$;

- a special charge (mine) was also detonated on the same 300 mm ASP wall sample. This mine

contains about 2 kg of HE explosive but not optimally shaped. The mine caused a crater of 300 mm x 500 mm to a depth of 100 mm. The back skin was bulged outwards by about 20 mm over an area of 0,4 $m^2$.

## 2.6 Static moment-rotation tests conducted on 200 mm thick ASP walling samples

From the above tests involving blast, it becomes apparent that the ASP section offers a great degree of ductility and is capable of deforming deeply into the plastic range, and thus can resist blast loads by absorbing large amounts of energy in internal plastic deformation work.

To assess this degree of ductility, static loading tests were performed to determine the moment-rotation relationship of the composite walling system in the direction of the "span" of the sheeting system.

Simply supported specimens, 2 m long, were loaded across the full width at mid-span by a knive edge load (see Figure 8). Support rotations were monitored by means of rotation gauges for support rotations up to $5^o$ and larger rotations were monitored by means of a centrally located deflection gauge. Load was applied and recorded through a Macklow Smith hydraulic testing machine.

Maximum unit bending moment values were plotted against angle support rotation as shown in Figure 9.

An angle support rotation of $13,5^o$ was observed without failure at the plastic hinge. It was not possible to pursue the loading curve as the midspan deflection of the specimen had reached the maximum clearance of the testing machine.

It is interesting to compare this large support rotation ($13,5^o$) as against what is normally reported for laced reinforced concrete ($12^o$) and ordinary reinforced concrete ($2^o$).

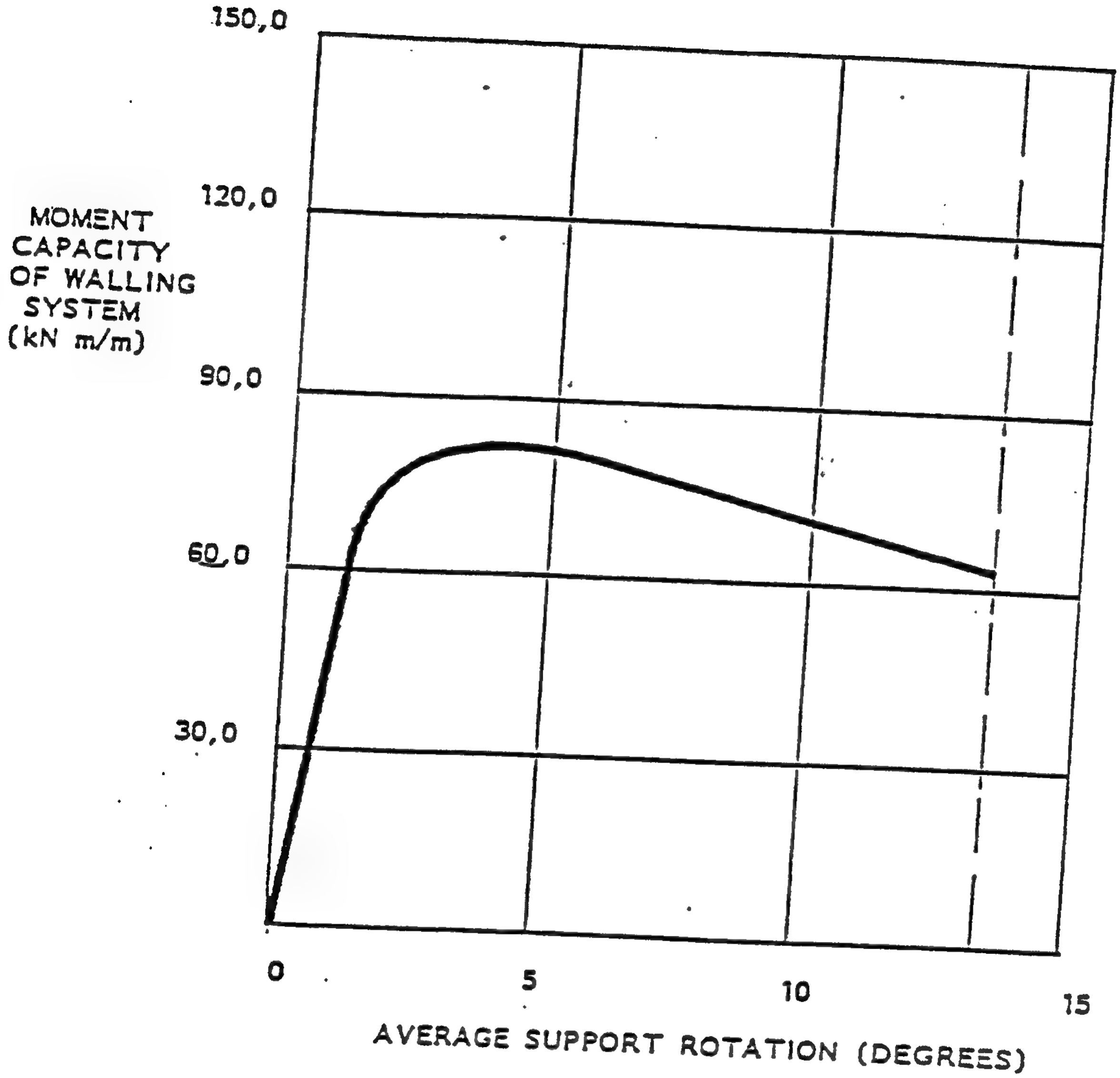

150,0
120,0
90,0
60,0
30,0
MOMENT CAPACITY OF WALLING SYSTEM (kN m/m)
0
5
10
15
AVERAGE SUPPORT ROTATION (DEGREES)

Figure 9.

## 3. CONCLUSIONS

The concept of using composite laced steel sheets and concrete as used in the ASP walling system offers some definite advantages over the traditional use of concrete in protective structures.

### 3.1 Ductility

The most important advantage of the system is its high ductility, as illustrated by the static moment-rotation test.

Resistance to blast is achieved by the deformation mechanism of the structure whereby the externally applied energy is absorbed and converted into internal deformation work. The larger the deformation accepted by the structure without failing, the better its performance against blast.

Figure 10 shows the comparative energy absorption capabilities of ASP, laced reinforced and ordinary reinforced concrete sections.

The high ductility is mainly the result of :

- the use of commercial grade mild steel for the sheets; this allows a high percentage of elongation of the sheets before failure;
- the lacing arrangement of the sheets whereby the lacing panels hold the compression side of the section in position and prevent the early buckling of the compression side;
- the confinement of the concrete into triangular zones which probably contributes to an increase in effective concrete strength.

### 3.2 Resistance to fragments

The ASP walling section has shown during the tests an excellent capability to resist fragments.

This is probably due to the staggered arrangement of the external sheets and the continuous barrier presented by the diagonal panels. Also, damage is very localized. The impinging fragment is

accepted and confined in the triangular zone formed by two adjacent lacing panels, and concrete destruction is localized within that triangular acceptor zone. Concrete cracks do not propagate through the wall.

### 3.3 Anti-spalling

The external sheets used as permanent formwork are placed at the extreme fibers of the section and provide thus natural anti-spalling plates containing the secondary concrete fragments which are customary in reinforced concrete elements subject to blast and primary fragments.

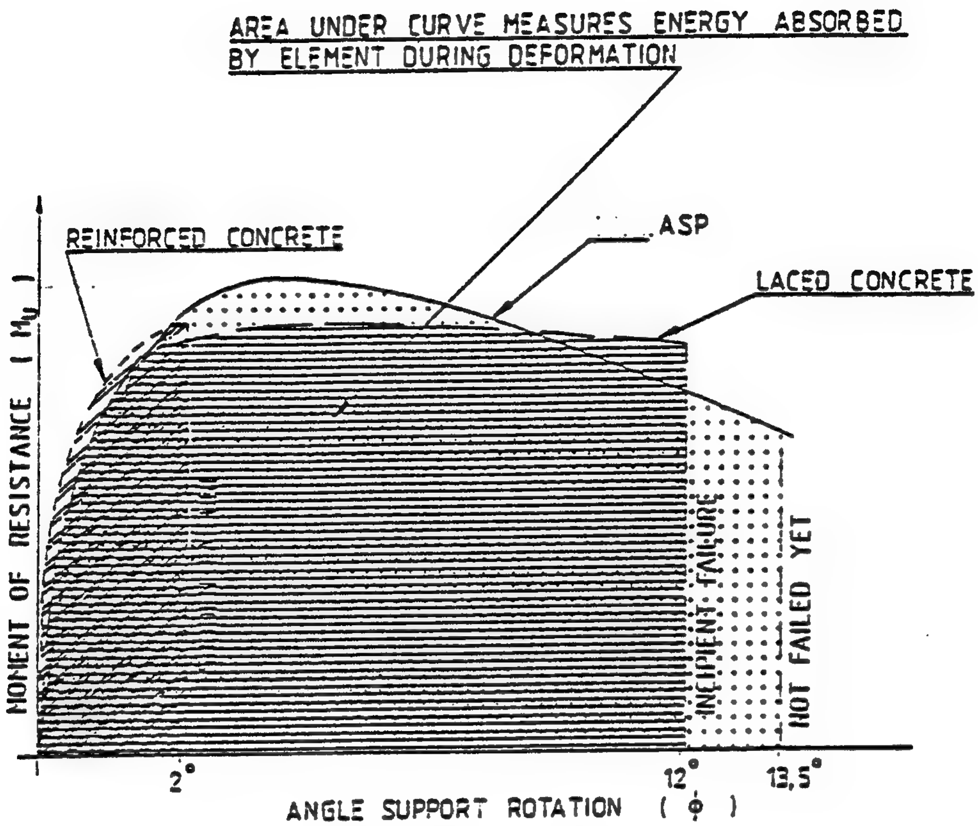
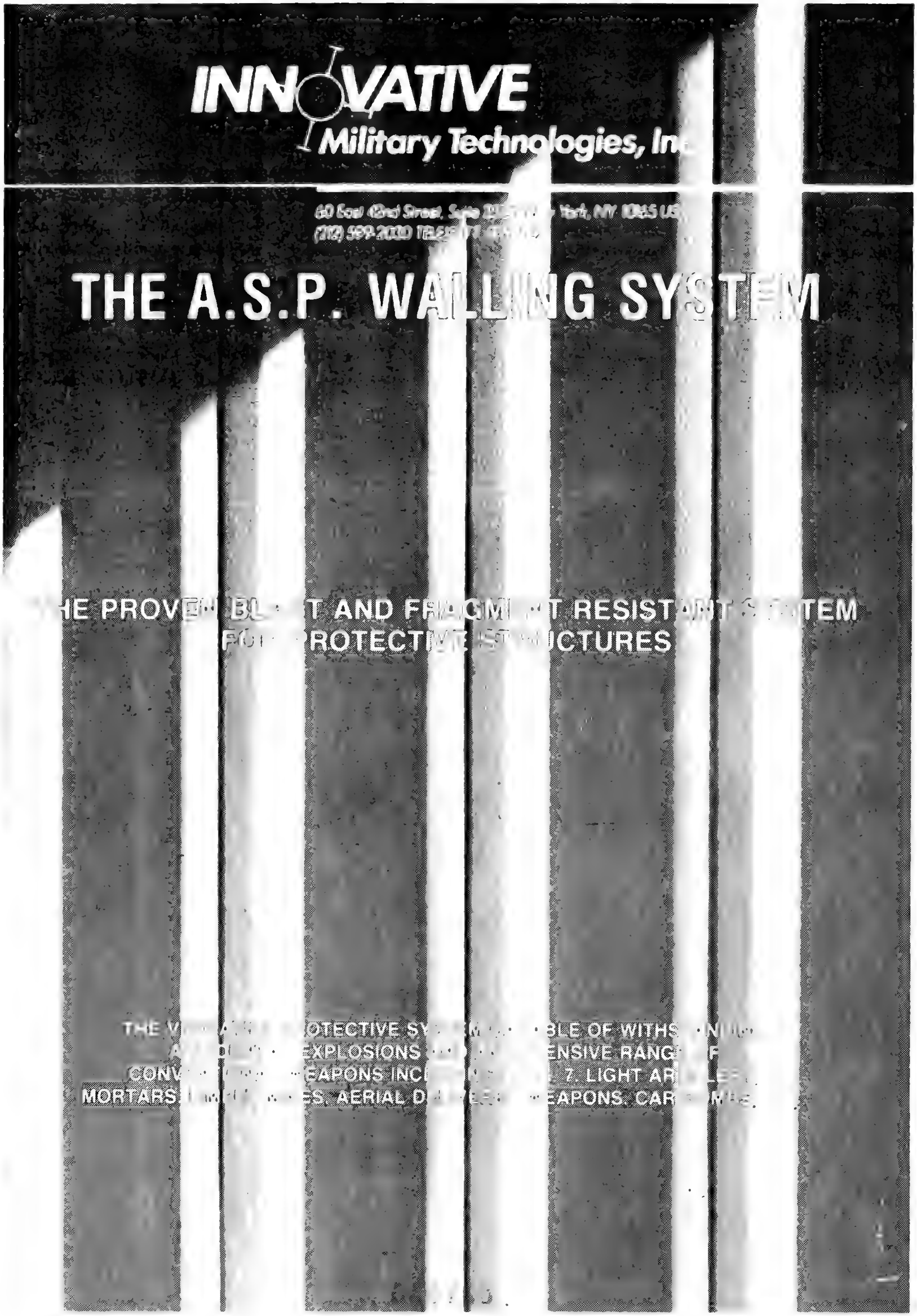



Figure 10.

Comparative Energy Absorption Capabilities of Reinforced Concrete, Laced Concrete and ASP Walling System.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THE A.S.P. WALLING SYSTEM

# THE A.S.P. WALLING SYSTEM

## THE PROVEN BLAST AND FRAGMENT RESISTANT SYSTEM FOR PROTECTIVE STRUCTURES

THE VERSATILE PROTECTIVE SYSTEM CAPABLE OF WITHSTANDING ACCIDENTAL EXPLOSIONS AND AN EXTENSIVE RANGE OF CONVENTIONAL WEAPONS INCLUDING R.P.G. 7, LIGHT ARTILLERY, MORTARS, LIMPET MINES, AERIAL DELIVERED WEAPONS, CAR BOMBS, ETC.

# CONTENTS

## 2. THE ASP WALLING SYSTEM

### 2.1 General Description

The ASP Walling system consists of formed metal sheets joined together to constitute both the permanent formwork and the reinforcement to the concrete, while at the same time acting as anti-spalling plates to contain fragments.

The basic component of the ASP walling system is a wall element (Fig. 1) consisting of interlocked external sheets. The two faces are tied to each other by diagonal lacing panels which, in zig-zag fashion, form a rigid permanent formwork into which concrete is placed (see photographs no. 1 and 2 in Appendix B).

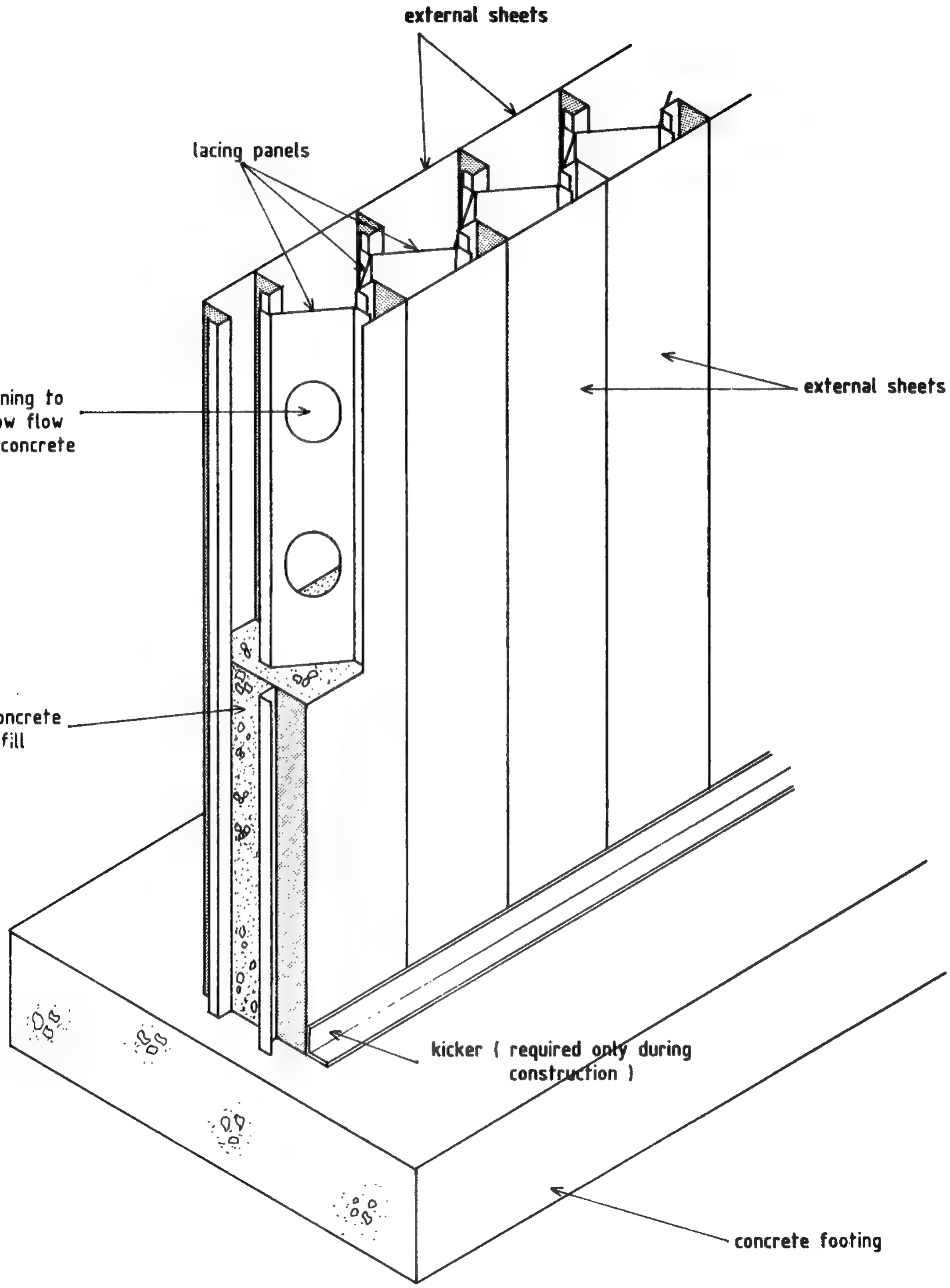
The ASP sheets provide the necessary reinforcement to the concrete. The external sheets are the tensile and compressive reinforcement while the diagonal lacing panels are the shear reinforcement. No additional reinforcement is needed except for reinforcing bars at top and bottom as a connection to the concrete roof and foundation.

The sheets are rolled in three modules : for 8" , 10" or 12" thick walls (nominal). Half module sheets are also standard. The standard sheet profiles are shown in Figs. 2 and 3.

Structures should be dimensioned to suit the half or full module of the required ASP walling to provide the most cost effective solution, though non standard dimensions can be accomodated.

The ASP Walling system produces a strong, ductile and fragment resistant component for the construction of protective walls and hardened buildings.

It is a versatile, easy-to-erect and cost-effective construction system.




Fig, 1

Isometric View of the Basic Component of the
ASP Walling System 000773

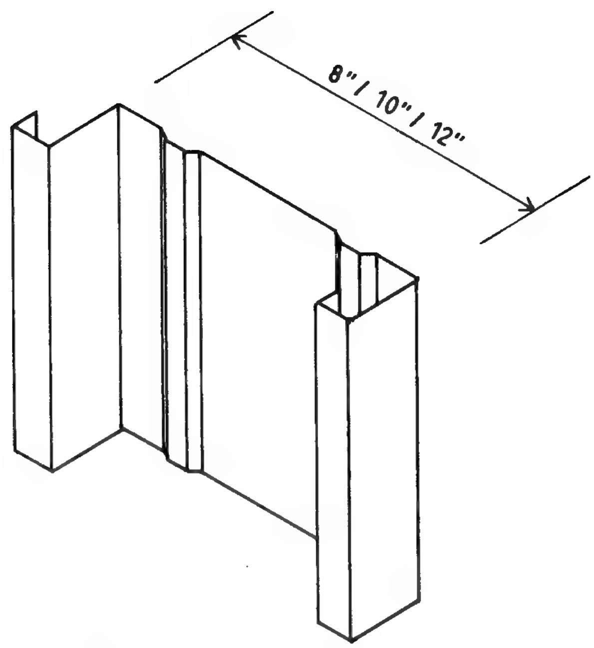



Fig. 2

ASP External Sheet
(viewed from inside)

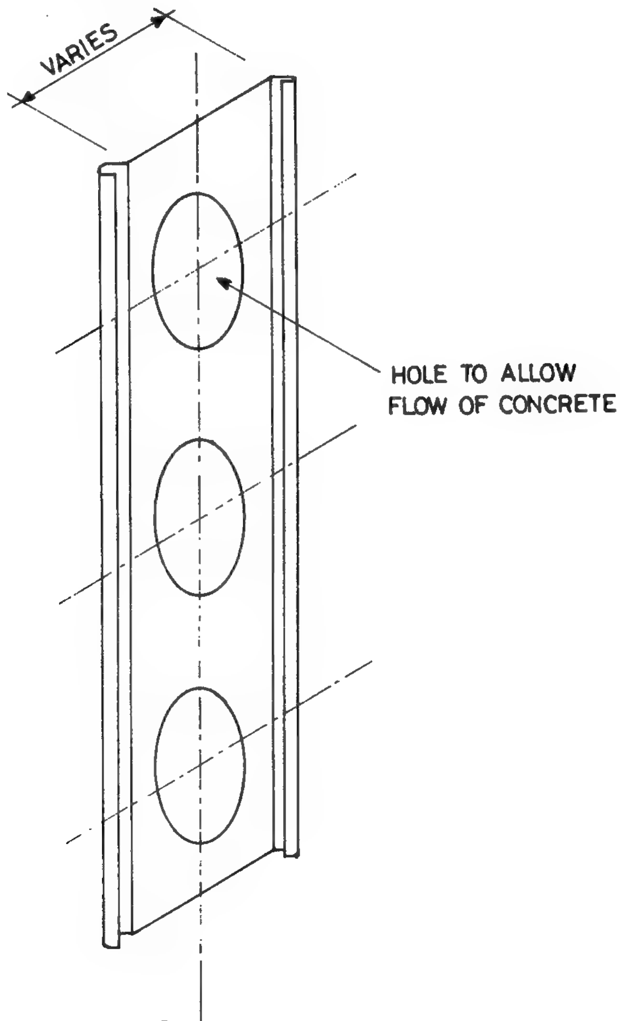



Fig. 3

ASP Diagonal Lacing Panel

## 2.2 Reinforcement to the ASP wall

The external steel sheets form the main reinforcement to the concrete. They provide the section with symmetrical tensile and compressive reinforcement. The steel ribs are deeply embedded in the concrete ensuring a good bond between the concrete and reinforcement.

The diagonal lacing panels not only form a lattice-work effectively securing the external faces to each other, but also act as uniformly distributed shear reinforcement.

No additional reinforcement, in the form of reinforcing bars, is required in the walls except for the starter bars from the foundation into wall (Fig. 4), corner bars at the connection between a wall and roof slab (Fig. 5) and straight bars at horizontal joints in the external ASP sheets (Fig. 6).

## 2.3 Fabrication of ASP walling material

The IMT design team will determine the required sheeting arrangement for a structure, taking the Contractor's programme into account.

The ASP sheets are rolled, generally using a Z275 galvanised commercial grade steel coil material, cut to the lengths detailed by the design team. Other materials such as stainless steel or coated steel can be provided for specialized applications.

## 2.4 Construction

After conventional concrete foundations are cast with reinforcing starter bars to project and tie into the walls (see photograph 3 in Appendix B) a scaffold is erected to provide the nominal support required to keep the wall upright. The ASP sheets are then erected and aligned against both a kicker angle secured to the foundation and the scaffolding support.

Because it is a modular system, layout arrangements are easily achieved. Because it is a standardised system the metal ASP sheets are easily and rapidly erected. The system does not require specialist labour and is thus easily handled by most general Contractors.

Due to this and the fact that the steel ASP sheets provide all the necessary reinforcement, the erection time for the ASP Walling can be up to 5 times faster than reinforced concrete systems.

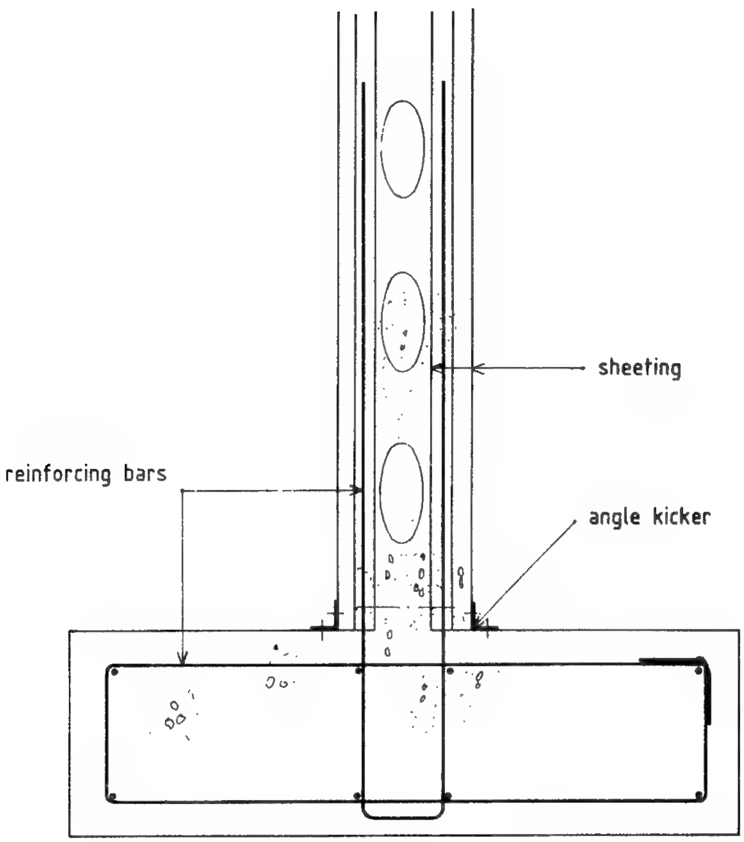
The external sheets easily interlock with each other at their shaped ribs in male-female fashion (Fig. 7). The sheets in the external faces are staggered so that the ribs may receive the lacing panels. These lacing panels are slid from the top and secured, as can be seen in photograph 4 in Appendix B.

However, a method of erection from the side has been developed enabling the ASP walling to be used in an existing structure where the normal construction procedure of erection from the top cannot be adopted (see photograph 5, 6 and 7 in Appendix B).

The assembled ASP sheets form a rigid permanent formwork into which the high slump concrete is placed. Pouring of the concrete must be gradual but is done very easily if the concrete mix is of the correct slump. The diagonal lacing panels are perforated with circular holes to allow the flow of the concrete through them (see Figs. 1 and 3).

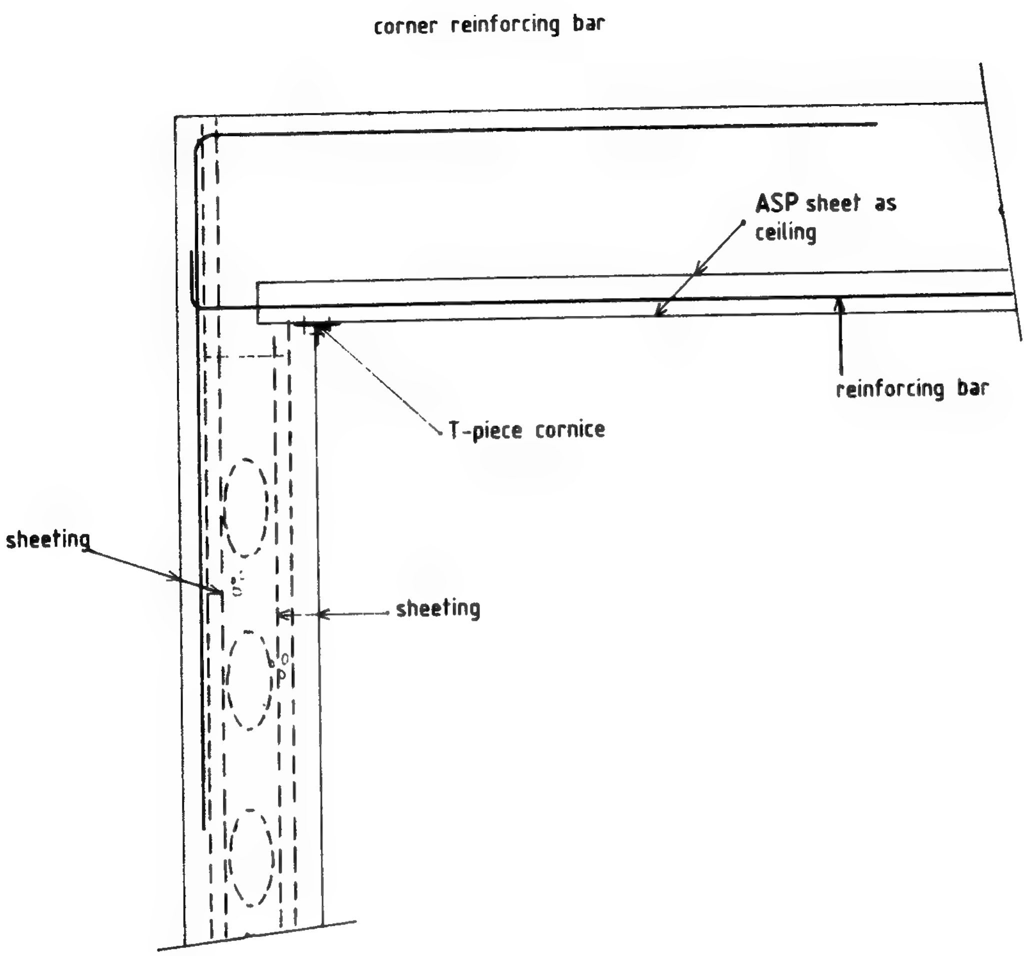
Complete wall sections, and even small structures, can be erected and concreted on off-site production lines, and then be transported to their final position.

A comprehensive brochure entitled "Specifications and Erection Guidelines for ASP walling" is available and gives detailed technical requirements as well as guidelines for the construction of the ASP system. If required a demonstration in the construction procedure can be given to Contractors.




TYPICAL WALL-FOOTING CONNECTION

Fig. 4




TYPICAL WALL-SLAB CONNECTION

Fig. 5

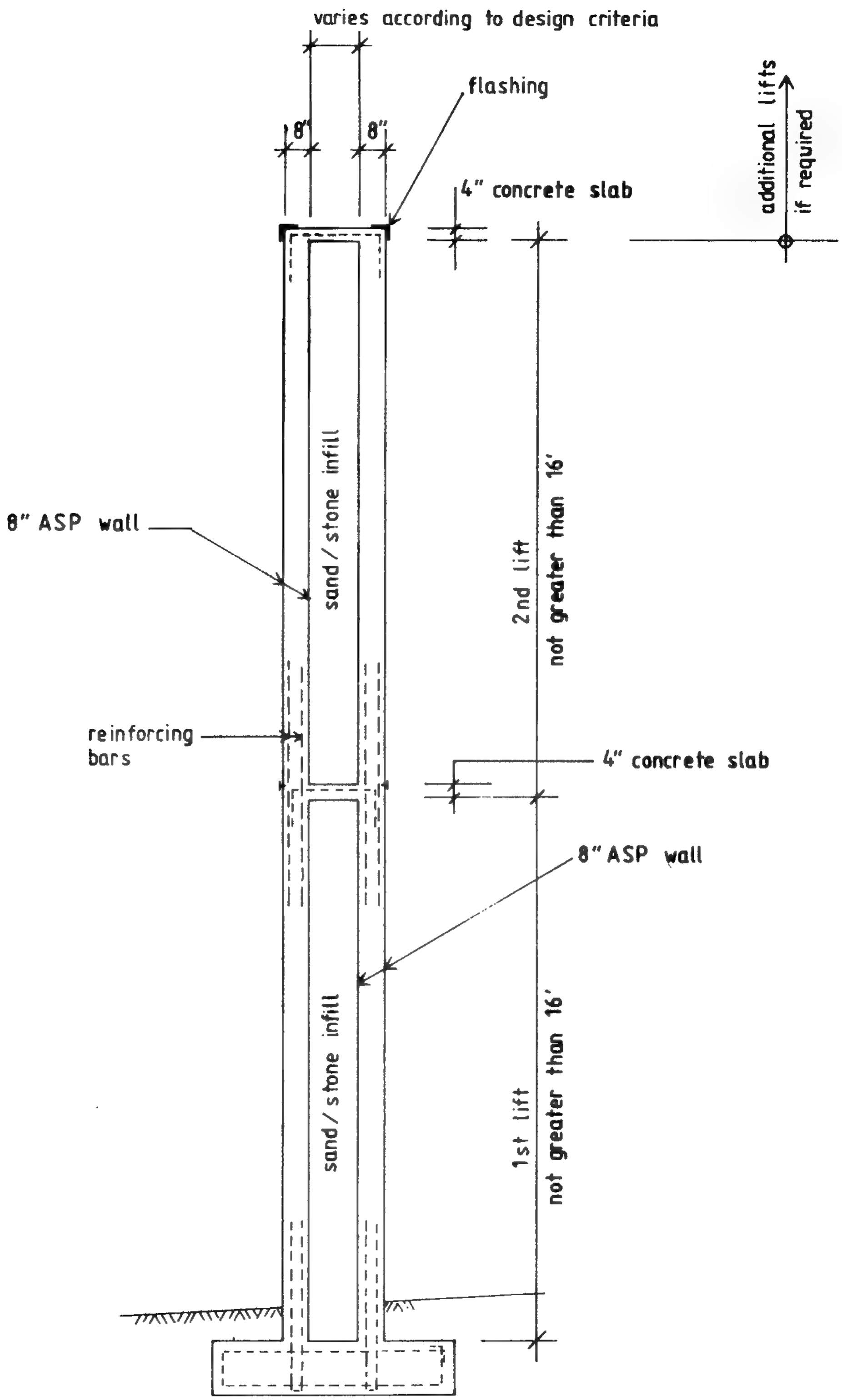
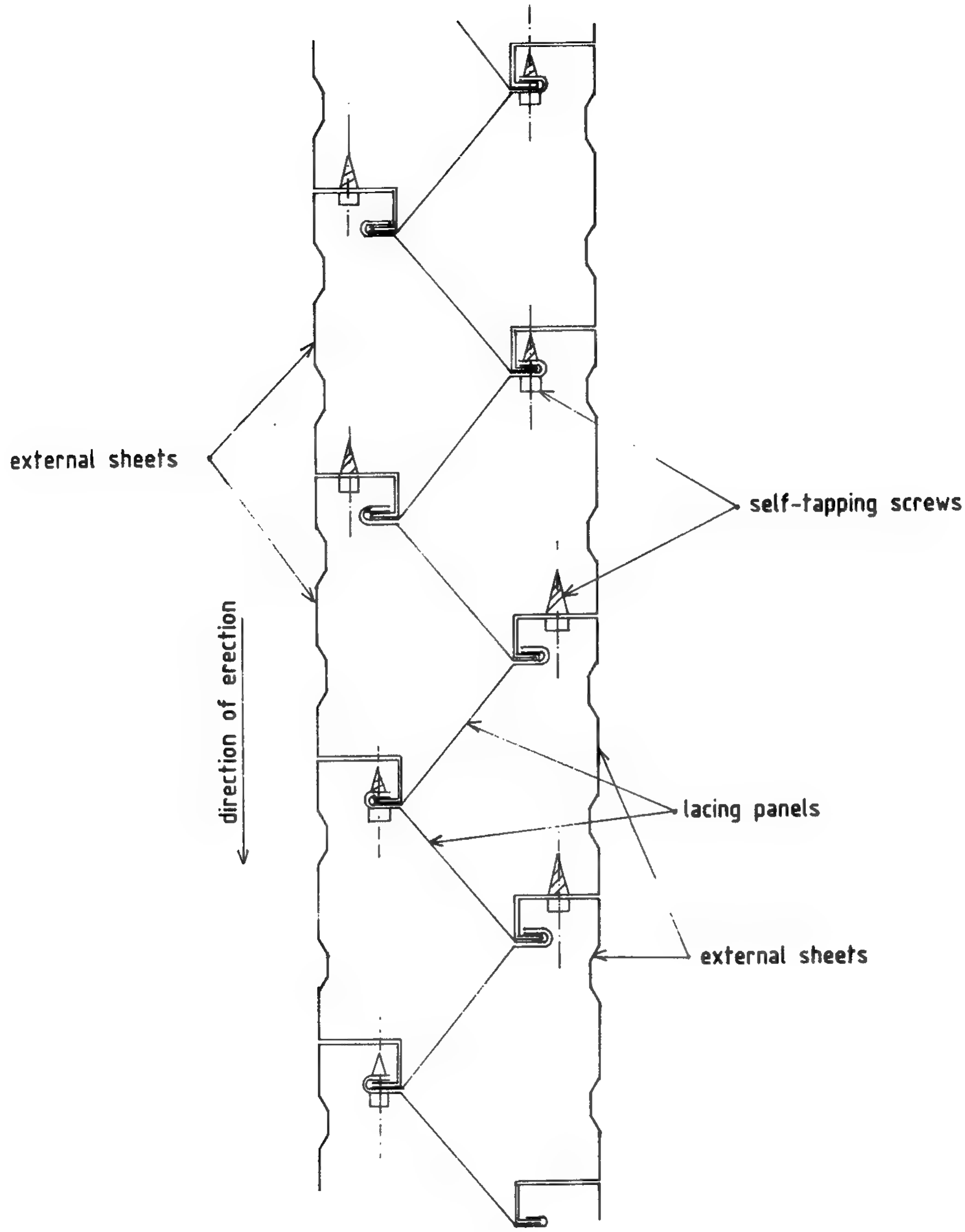



Fig. 6

A Typical High ASP Wall




DETAIL OF SHEET ASSEMBLY : PLAN VIEW

Fig. 7

## 2.5 Effectiveness

As a guide, the ASP wall will generally be half as thick as a conventional reinforced concrete wall designed for the same level of protection against blast and fragments, although in certain instances a 10" ASP wall has proved to be equivalent to 2'-0" of reinforced concrete.

The reduced thickness of the ASP wall provides a distinct weight advantage over its reinforced concrete counterparts which enables e.g. transportable sections to become effective. In existing buildings it may also become feasible to construct protective ASP walls where the heavier, reinforced concrete counterparts would overstress the existing structure.

The ASP wall has an additional advantage over a reinforced concrete wall as it offers natural anti-spalling plates to contain concrete fragments, which are often a major danger in protective structures.

Another major advantage over conventional reinforced concrete is the fact that cracks do not propagate in the system, and damage under attack is thus very localised. After an attack the structural integrity of the ASP wall is therefore not compromised to the same extent as with reinforced concrete. It is also easier to carry out repairs since the damaged area is smaller in extent.

The system is suited to upgrading and this aspect can be taken into account in the design. This allows the implementation of the desired protection in phases, as well as allowing for the upgrading to take into account possible higher weapons criteria in the future.

## 2.6 Cost

The ASP wall has been proved to be cheaper than a conventional reinforced concrete structure for the same level of protection. The cost increase for the permanent formwork is more than offset by the savings in labour, concrete and reinforcement.

As a guideline, it has been found that the ASP system costs between 50% and 70% of the cost for a comparable reinforced concrete protective system.

## 2.7 Doors and Services

EXP doors specially designed to meet the same weapon criteria as the ASP walling are part of the system, and are built in as a complete unit which is made to order. Other services can be readily accommodated in the system in a manner which provides the same level of protection.

## 2.8 Corrosion

Anti-corrosion precautions are always taken into account to provide the necessary resistance to corrosion for individual sites. The galvanised ASP sheets automatically give a degree of galvanic protection.

Corrosion protection options available include the use of:

- precoated galvanised coil material
- stainless steel coil material
- various external protective coatings
- joint sealants

## 2.9 Aesthetics

Protective structures are usually functional and of a very austere nature.

The slight flutes in the ASP external sheets together with the vertical lines at joints between ASP sheets diminish this austere character. In addition, the use of coloured coatings results in some very attractive structures as can be seen in photographs 8 to 10 in Appendix B.

# 3. THE EXP DOORS

## 3.1 Description

EXP doors are designed to provide the required degree of protection against intrusion, explosive charges, RPG rockets, blast and fragments.

The EXP doors are in two parts :

- a "wrap around" frame which is concreted into the protective structure;
- the door itself which can be installed at a later and more convenient time.

The construction of the door panel varies according to the type of protection required.

All doors are easily moved on their hinges, can be locked in the closed position and have sensors to monitor the status of the door. They are fitted with a crash-bar mechanism when needed for emergency exit.

## 3.2 Design

Great care is given to the design of the hinges and of the closing mechanisms, and all doors are designed not only to resist a given attack, but also to remain functional after that attack (i.e. can be opened by hand).

Large, heavy sliding doors may also be designed with all the necessary driving accessories, tracks and mechanisms in such a way to ensure safety and integrity against attack criteria.

Original door designs have been produced and tested under full scale conditions.

## 3.3 Application

In any protective structure the access points must have the same level of protection as the remainder of the structure.

The EXP doors fulfil this requirement since they are individually designed for specific applications. They have been used in reinforced concrete structures as well as with the ASP Walling . Various examples can be seen in the photographs of Appendix B.

## 3.4 Availability

All doors are made to order and can be supplied as separate units or as part of a protective design using the ASP Walling.

## 4. APPLICATION

### 4.1 The protection given

The ASP/EXP System is an economical and effective means for the provision of protection against explosions, accidental or otherwise, and weapons effects. In addition to the protection offered by the ASP walling against blast and fragments, the external envelope of continuous metal sheets creates a natural Faraday cage which can be utilized to give protection against electromagnetic pulse (EMP).

There are three main areas where protection is required :

- for military protective structures designed for the threat of conventional warfare;
- for targets of terrorist attacks;
- for areas where accidental explosions may occur during normal operations.

### 4.2 Design services

The ASP Walling is extremely versatile and can be used for anything from a straight wall to a large hardened, i.e. protected, structural complex.

Individual protective requirements are designed by specialists in the field of protective structures, to meet the client's requirements with regard to protection.

The design service forms an integral part of the ASP system which is offered as a turn-key project or on a design and supply basis.

Technical information regarding the basic design requirements of a protective structure, and how these are met by the ASP system are given in Appendix A.

## 4.3 Protective walls

Protective walls are erected in various areas, such as:

- around or inside existing soft (i.e. unprotected) buildings;
- around open-air installations like transformers, petrol tanks, reservoirs, etc.;
- as containment walls around sensitive facilities like ammunition dumps, LPG tanks, etc.;
- as transportable protective walls.

ASP protective walls are constructed as straight cantilever walls or in "sandwich" form with air gaps of various dimensions or with in-fill material (Fig. 6). See photographs 17 and 18 in Appendix B.

Removable panel sections may be introduced in a perimeter wall to allow for large access openings which are infrequently used. See photographs 19 and 20 in Appendix B.

Where future expansion of the area being protected is envisaged, transportable wall sections can be used to facilitate the subsequent re-alignment of the protective wall.

## 4.4 Hardened buldings

Hardening of buildings is required in a multitude of circumstances:

- for the military : logistics and fortification buildings, above ground and underground shelters, ammunition magazines, etc.;
- for key points installations : hardened control rooms, communication centres, computer rooms, capital spares depots, etc.;
- as operational buildings : explosive testing rooms, explosive storage facilities, etc.

In the ASP system, the floor of a hardened building is generally of simple reinforced concrete construction, preferably in the form of a raft foundation, with reinforcing starter bars to connect into the ASP walls. The roof is generally a solid reinforced concrete slab of composite construction with ASP external steel sheeting as permanent shuttering to the soffit. These soffit sheets have the advantage of forming an anti-spalling shield.

## 4.5 Doors

All protective structures require an access route for the use of personnel and materials.

Whether the protective system used is the ASP walling or a reinforced concrete alternative, the use of the EXP doors ensures that the entire stucture has the same level of protection.

## 5. TESTS

The system has been extensively tested and photographs 21 to 33 in Appendix B show some of the tested samples.

Tested results are available to confirm, inter alia, the following :

- That a thinner ASP wall section will give the same protection as a thicker conventional reinforced concrete section.
- That the ASP wall in "sandwich" construction will offer full protection against direct hits of RPG 7 rockets. In fact the "sandwich" ASP wall offers full protection against virtually the full range of conventional threats, i.e. direct hits by light artillery of the 122 mm type, mortars, blast and fragments resulting from explosions caused by general purpose aerial delivered weapons, breaching effect of placed charges, etc.
- That ASP walls will give protection against blasts resulting from normal military type explosive used in the standard manner of a terrorist attack.
- That an 8" ASP wall will resist the blast and fragments generated by a near miss of general purpose aerial delivered weapons.
- That at the displacement limit of a static load test bed, the support angle rotation was $13{,}5^{0}$, without the failure of the ASP wall unit being tested.
- That doors have been designed which have been tested against various placed charges, bullet penetration, blast and fragments generated by explosions caused by general purpose aerial delivered weapons, the RPG 7 rocket, and has proved the ability of the door hinges and closing mechanisms to remain effective and functional during and after an attack.

# APPENDIX A

## BASIC REQUIREMENTS OF A PROTECTIVE STRUCTURE

## 1. RESISTANCE TO BLAST

Any explosion causes blast and protective structures must be designed to resist this blast effect.

A blast is a pressure wave characterized by a high peak pressure applied over a very short time period producing a severe shock (impulse) on any element standing in the way of the blast wave. The impulse is normally so intense that the structures under attack are plastically deformed.

Resistance to blast is achieved by the deformation mechanism of the structure whereby the externally applied energy is absorbed and converted into internal deformation work. The larger the deformations accepted by the structure (without failing), the better its performance against blast.

The ASP Walling section has an excellent capability to deform because of the following:

(a) The sheets are made of commercial grade mild steel with a high degree of ductility.

(b) At high levels of deformation, concrete is cracked, disengaged or crushed in which case the moment of resistance of the section is only provided by the reinforcement. Compression reinforcement then becomes essential and it must be adequately restrained by lacing to prevent buckling.

This is achieved at its best in the ASP section where compression reinforcement is always equal to the tension reinforcement and where both reinforcement layers are safely secured to each other by the lacing panels.

(c) The ASP sheets, although mainly unidirectional, have some orthotropic behaviour and this helps the redistribution of stresses and gives the system a high degree of plasticity.

Deformation due to flexure in the plastic range is normally measured by support angle rotation.
Conventional reinforced concrete is known to only accept a maximum support rotation of $2^0$ which is a restricting factor. Because of this, current practice advocates the use of laced reinforced concrete whereby symmetrical layers of reinforcement are laced together by numerous and intricate lacing reinforcing bars that need accurate bending and placing. Laced reinforced concrete sections accept support rotations up to $12^0$ with a normal design standard being $6^0$ to $8^0$.

Tests have indicated that elements of ASP construction accept support rotation of at least $13{,}5^0$ and can thus perform better than laced reinforced concrete.

When reinforced concrete is subjected to blast, spalling of the rear concrete face can occur as well as scabbing of the concrete cover resulting in the formation of concrete fragments flying off at high velocities. This fragmentation phenomenon is often critical and requires special precautions such as anti-spalling plates solidly fixed to the inside faces of the concrete elements.

The problem is elegantly solved by the ASP concept where the main reinforcement, in the form of sheets, is actually placed at the outside extremeties of the section eliminating concrete cover and providing a natural anti-spalling shield to contain fragments.

## 2. RESISTANCE TO FRAGMENTS

Fragments are penetrating projectiles. They may be anything from bullets to shrapnel resulting from the rupture and dispersion of the metal casting of explosive shells.

A protective structure must resist the penetration of fragments.

This is normally achieved by selecting suitable hard material for the protective element and/or enough material thickness.

Because of the staggered arrangement of the outside sheets and of the continuous barrier presented by the diagonal panels, the ASP walling section offers a superior resistance to fragment penetration over ordinary concrete. The confinement of the concrete into triangular zone also creates a tri-axial state of stress condition that greatly enhances the resistance capabilities of the concrete. This has been admirably borne out by test results.

Results of tests lead to the following comparitive table of equivalent thicknesses :

| ASP section | Concrete counterpart |
|---|---|
| 8" | 16" |
| 10" | 24" |
| 12" | 36" |

In addition, the natural anti-spalling feature of the system reduces the danger of secondary fragments.

The diagonal panels also provide the following advantages:

(a) Concrete cracks induced by impinging fragments do not propagate but remain confined within the acceptor triangular zone defined by two adjacent lacing panels and the exterior panels.

(b) Penetrating fragments are often deflected upon hitting the diagonal panels.

## 3. RESISTANCE TO PLACED CHARGES

A placed charge (such as a limpet mine) is an explosive device placed in contact with a structural element with a view to destroy the element by contact explosion.

A protective structure will offer resistance to the breaching effect of a placed charge by a combination of deformation and resistance to penetration. Shear resistance is also important.
The ASP section provides the answers to all these requirements.
The large amount of uniformly distributed shear reincorcement provided by the lacing panels is a great contibuting factor.

An 8" thick ASP section will resist the explosion of a Soviet limpet mine. The concrete equivalent would be 15" of heavily reinforced concrete.

## 4. RESISTANCE TO HOLLOW CHARGE PROJECTILES

A well-known terrorist weapon is the RPG7 rocket launcher. The rocket contains a hollow-charge device which, on detonation, creates a concentrated high velocity jet that has extraordinary penetrative capabilities. It will penetrate up to 3'-0" of concrete or 12" of steel.

A common concept in the protection against hollow-charge projectiles is to predetonate the rocket by an activator screen at a suitable stand-off distance from the target. If the stand-off distance is not available, an absorbing element must be interposed between the activator and the target or, if there is no room at all for stand-off, one strong protective element combining the functions of the activator and the absorber must be placed in front of the target. Such a strong element may be a thick concrete wall (about 3 feet thick) or, as in the ASP system, a sandwich wall consisting of two skins of walling with in-fill material such as hard stones (Fig. 6 and photographs 17 and 18 in Appendix B).

This tested ASP solution is more economical and offers a wider range of protection than the solid concrete alternative.

Detonation of hollow-charge projectiles is normally caused by activation of the fuse on impact with a solid element. Commonly used are **contact fuses** that activate on impact with even relatively thin elements (such as a wire mesh fence) but there are also various types of **impact fuses** that will only activate on impact with stiff, solid elements.

The 8" ASP section will detonate any type of fuse. It is thus fully reliable as an activator screen and has the additional advantage over the popular mesh screens that it unsights the attackers.

## 5. RESISTANCE TO INTRUSION

A protective structure must prevent forced entry.

This will normally be achieved if the principle of uniform protection is applied, meaning that all components must be designed so as to offer an equal level of protection.

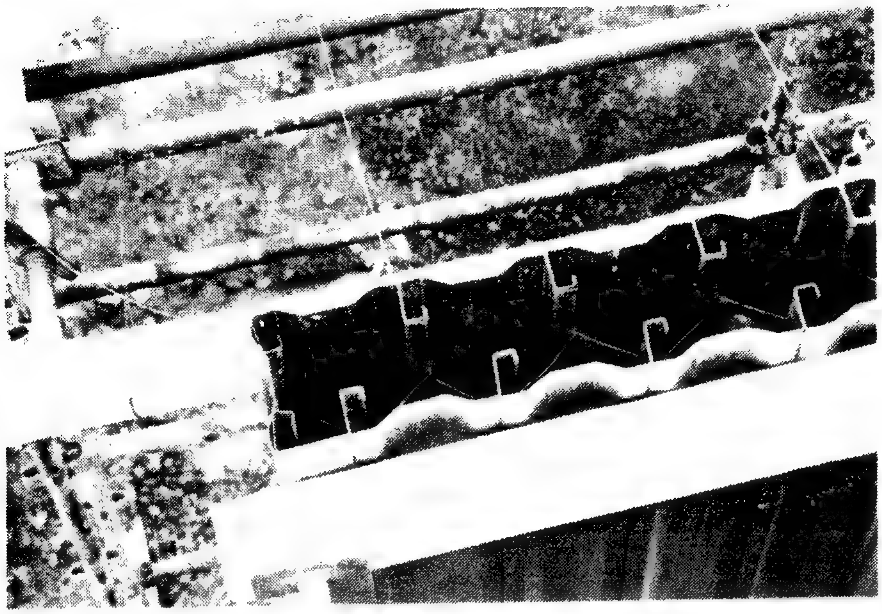
A hardened building constructed with strong walls but fitted with doors of inferior resistance would not offer uniform protection.

Adequate anti-intrusion capabilities of a protective structure are ensured by the correct design of all the components including all openings, windows, doors etc.

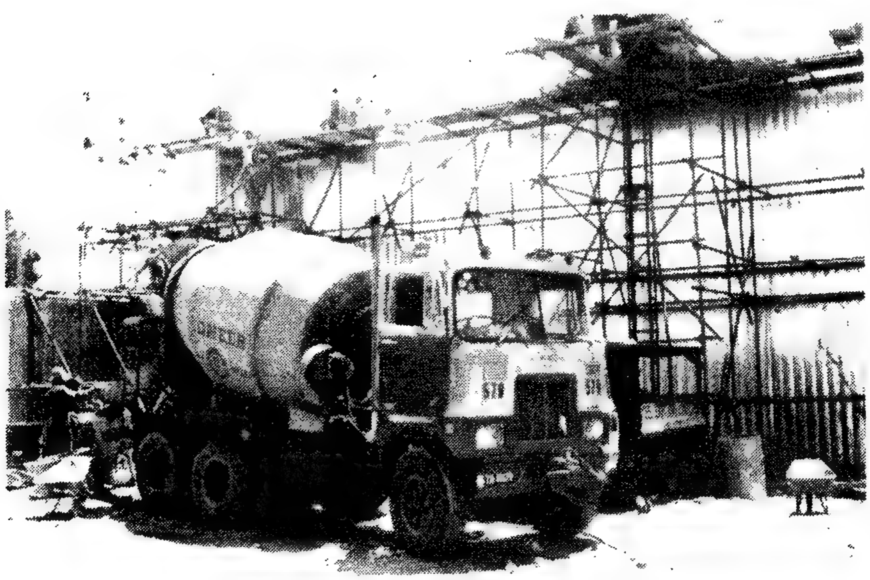
This is provided for in the ASP system where all apertures are specially designed.

APPENDIX B

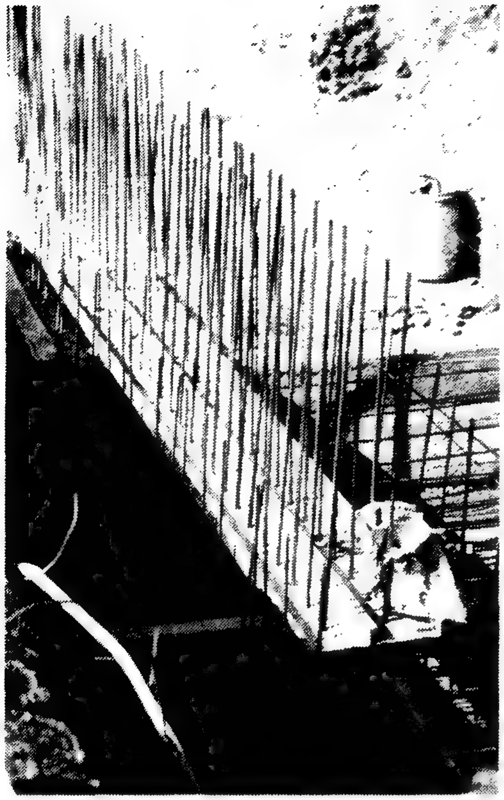
Photographs



Photograph No 1
View of erected ASP wall prior concreting



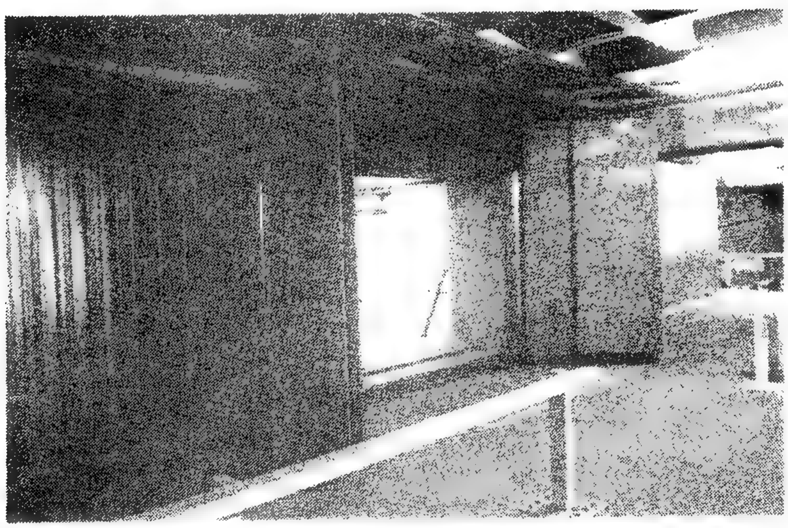
Photograph No 2
Concrete being poured into the erected sheets.
Note the nominal support needed

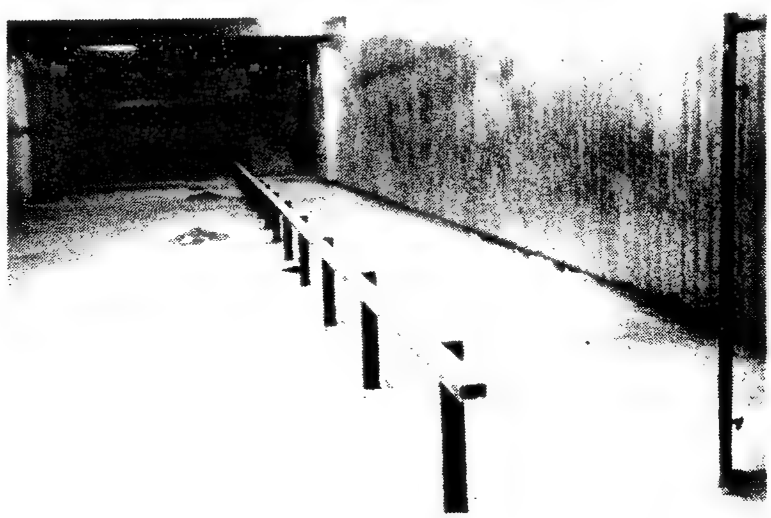


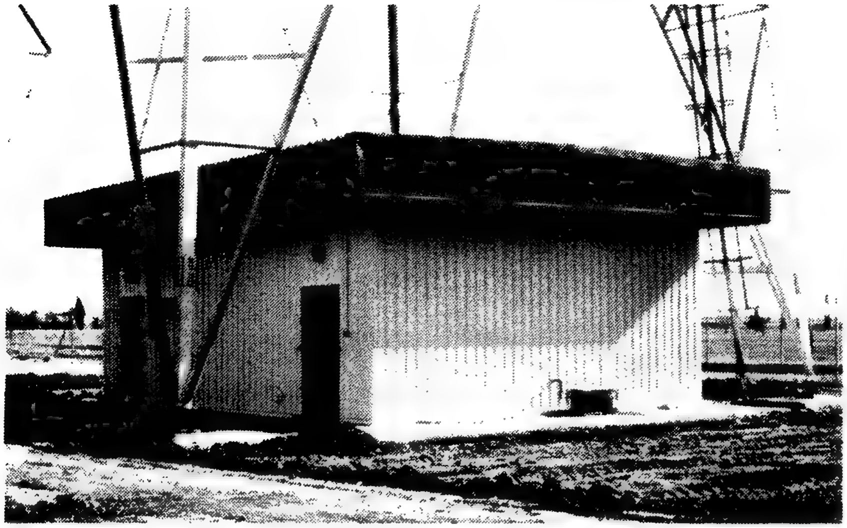
Photograph No 3
Reinforced concrete foundation with reinforcing bars projecting into the wall.

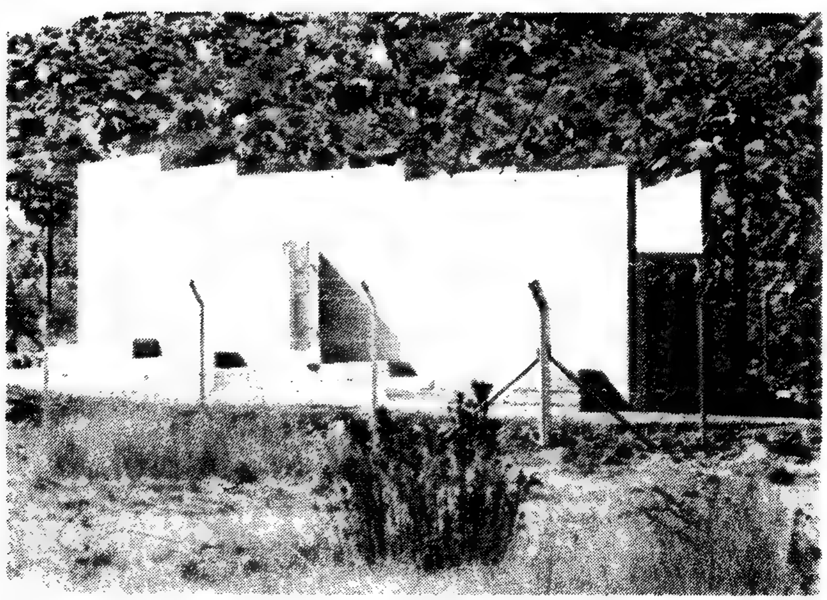
Photograph No 4
A lacing panel joining the two faces of the wall is slid into position from the top.

Photographs No
5, 6 and 7.
ASP walls constructed
in the confined
conditions of
existing structures.

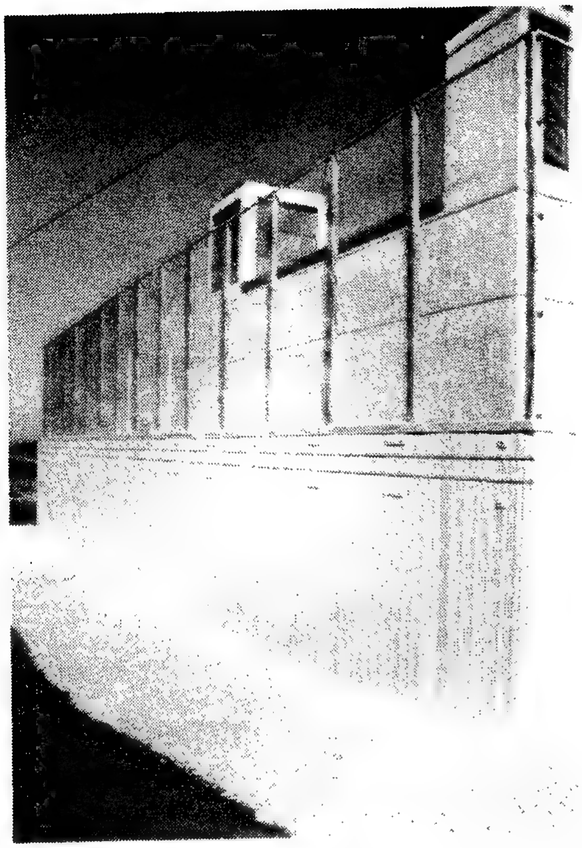






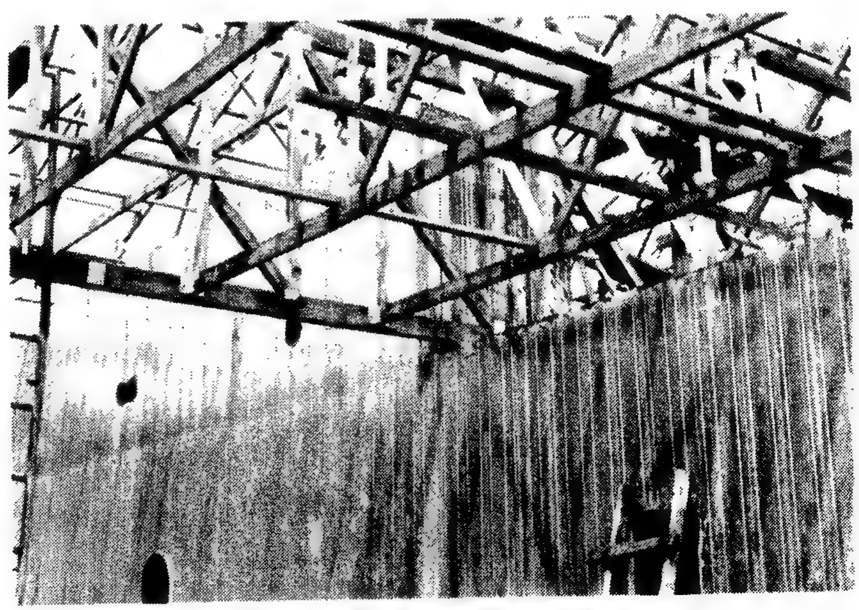


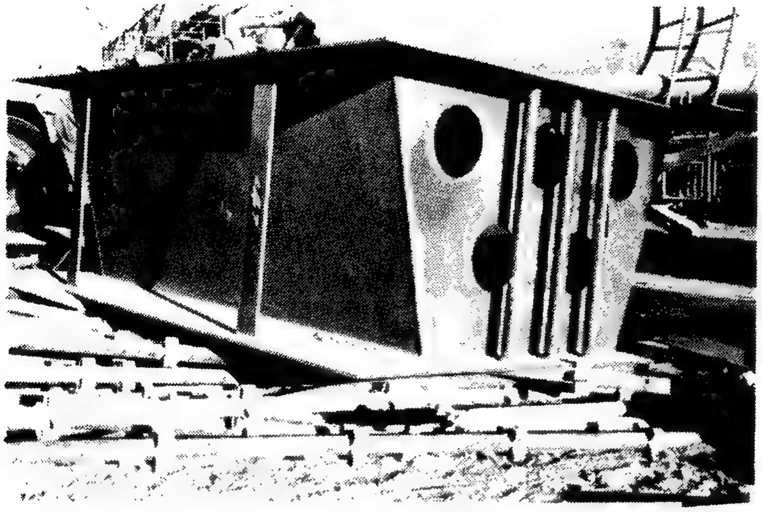
Photographs No 8 and 9.
Examples of ASP structures



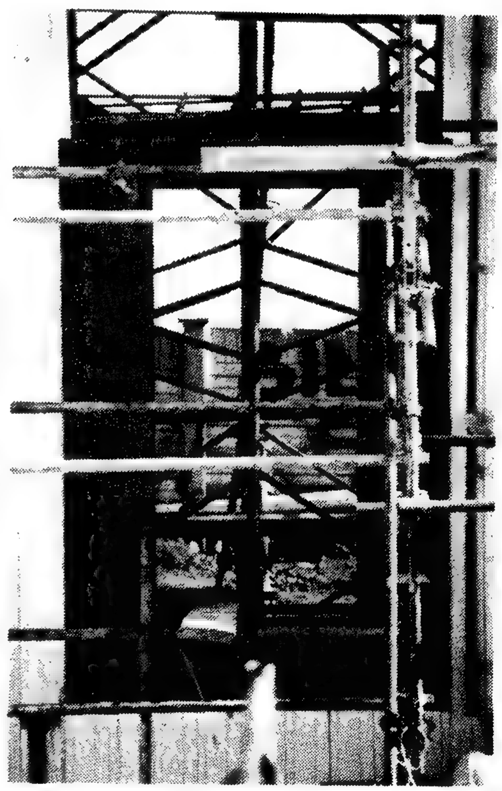
Photograph No 10
An example of an ASP protective structure.

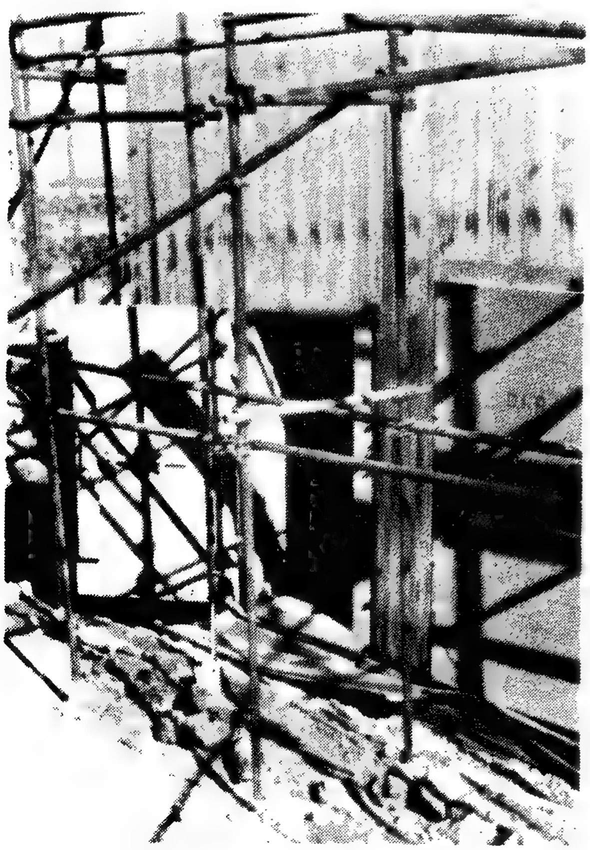
Photograph No 11
An ASP barrier wall in an industrial explosive facility.



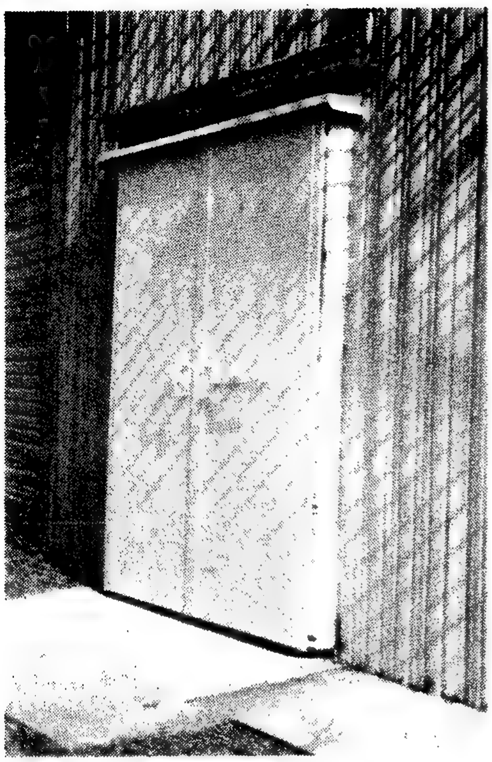


Photograph No 12
An EXP door frame
before erection

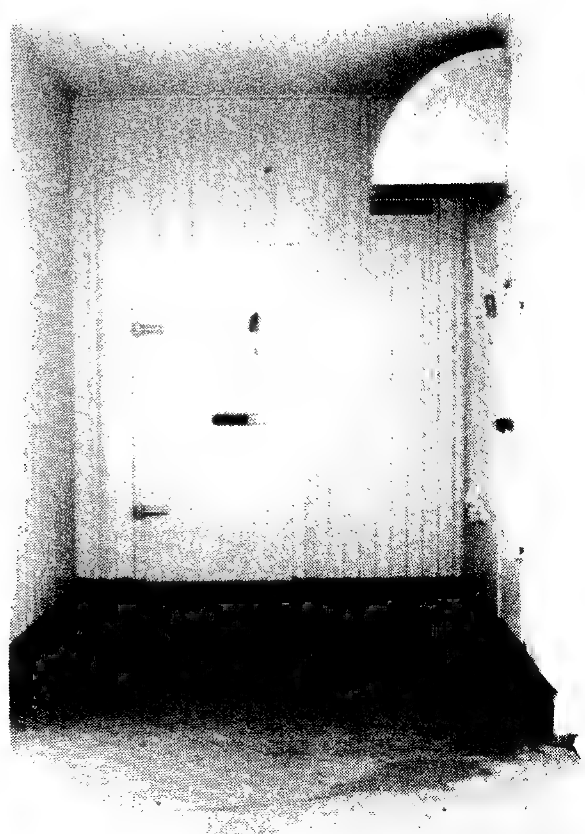


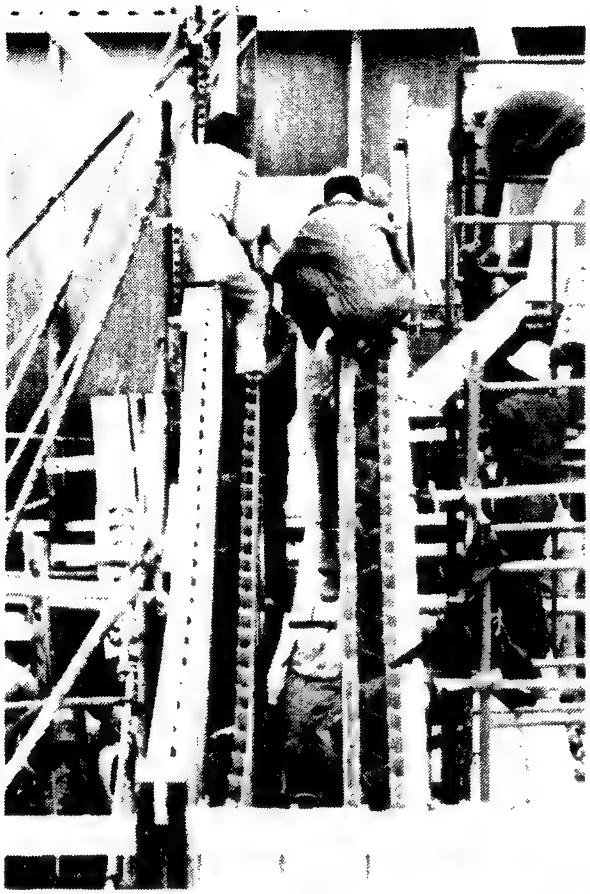


Photographs No 13 and 14
EXP doors and frames
during erection

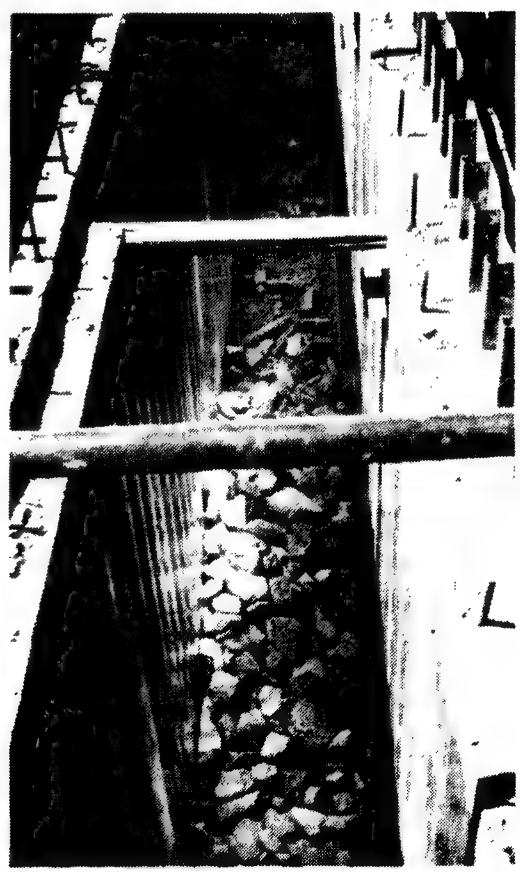


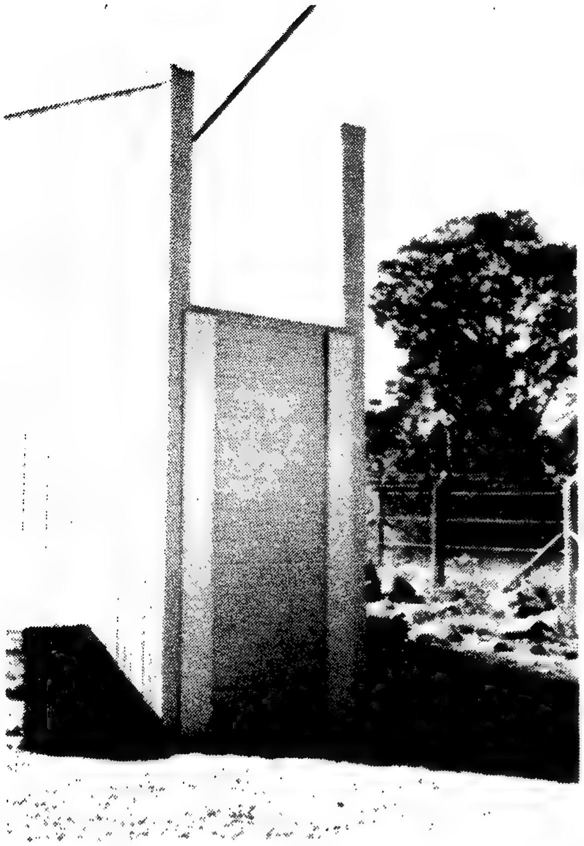
Photographs No 15 and 16
Examples of EXP doors



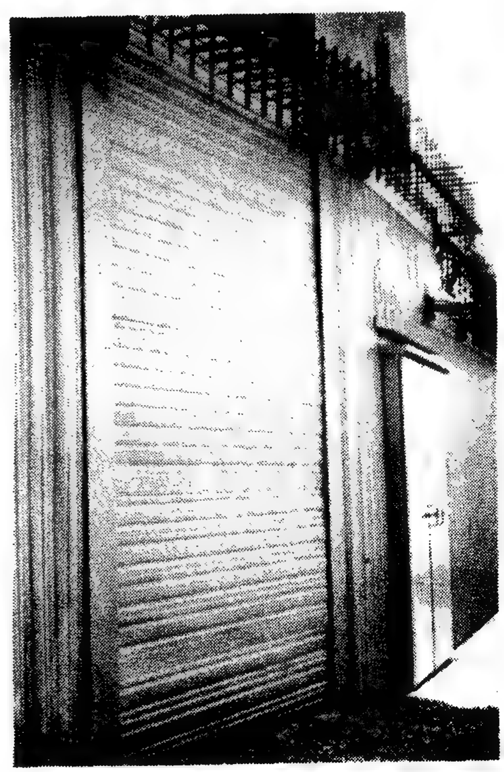


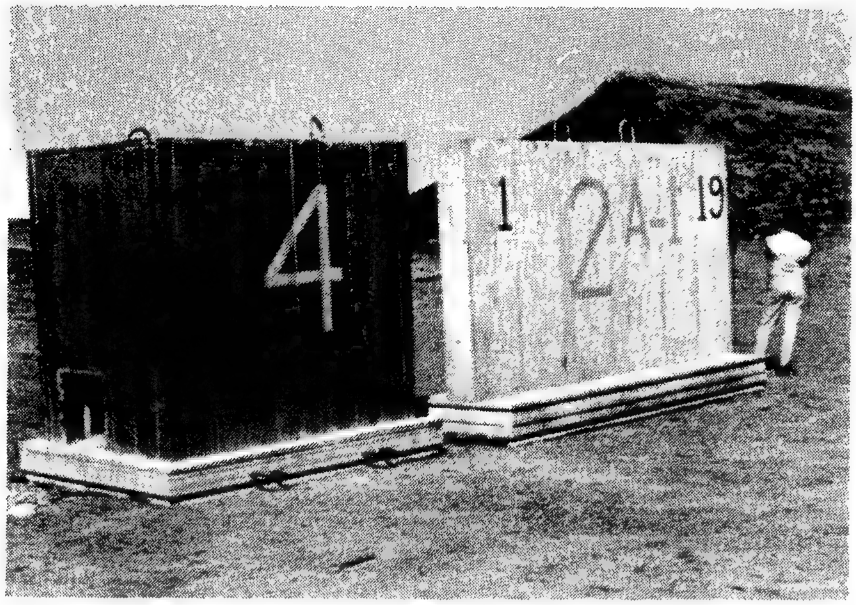
Photographs No 17 and 18
ASP sandwich walls with
stone in-fill



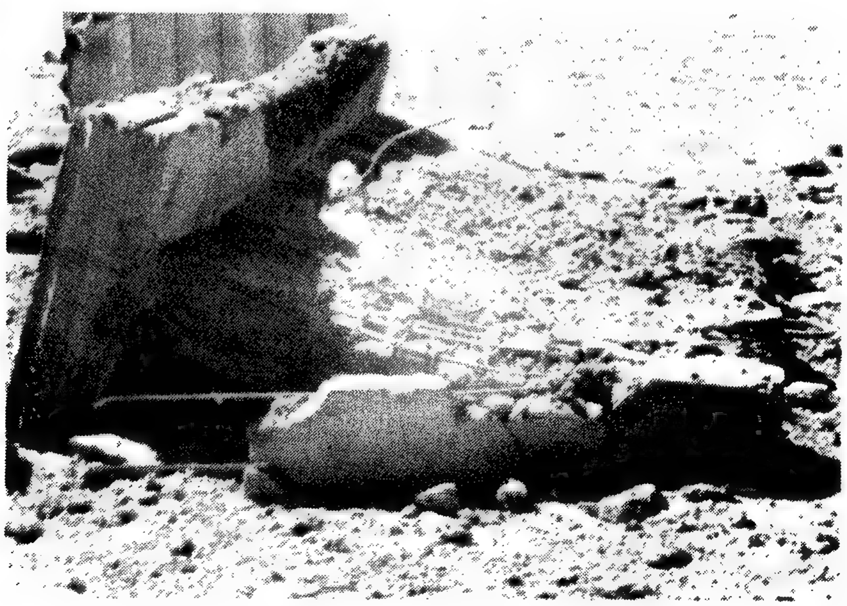


Photographs No 19 and 20
Examples of ASP removable panels



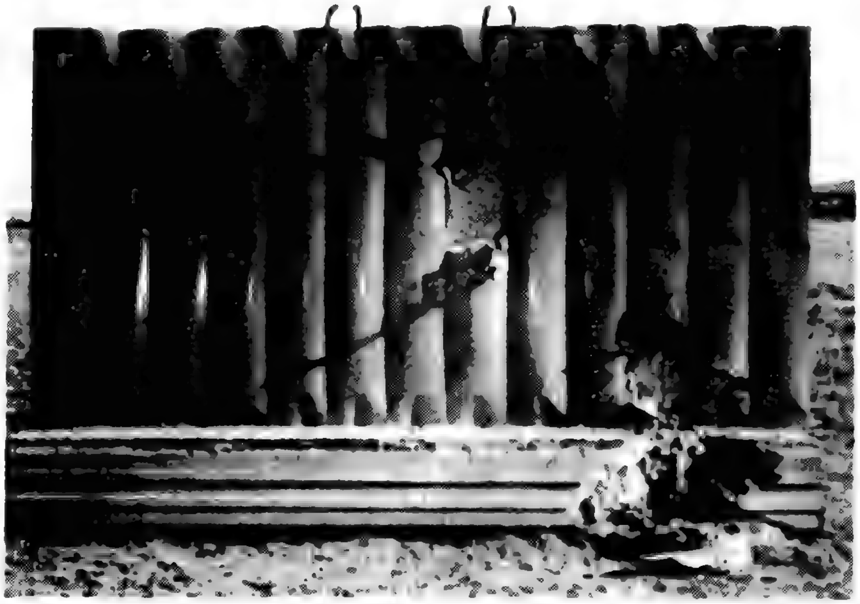


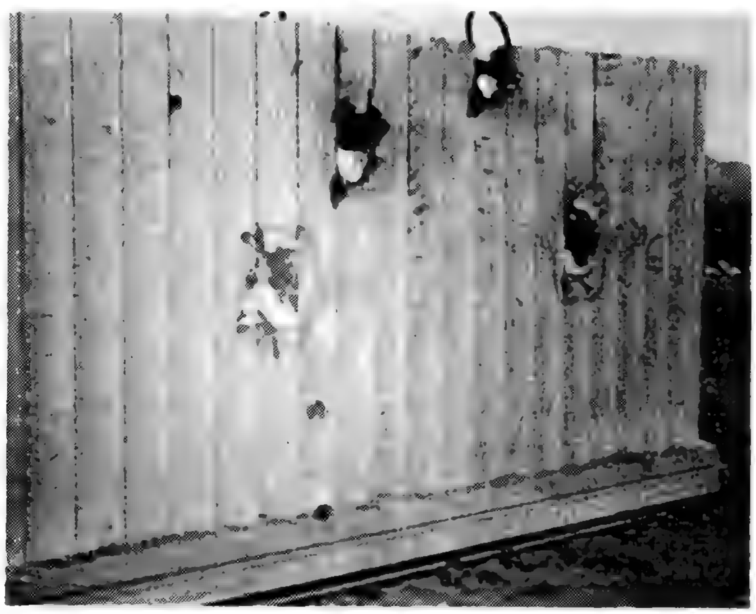

Photograph No 21
Samples before test.
An ASP box structure (left) and a conventional reinforced concrete wall (right).



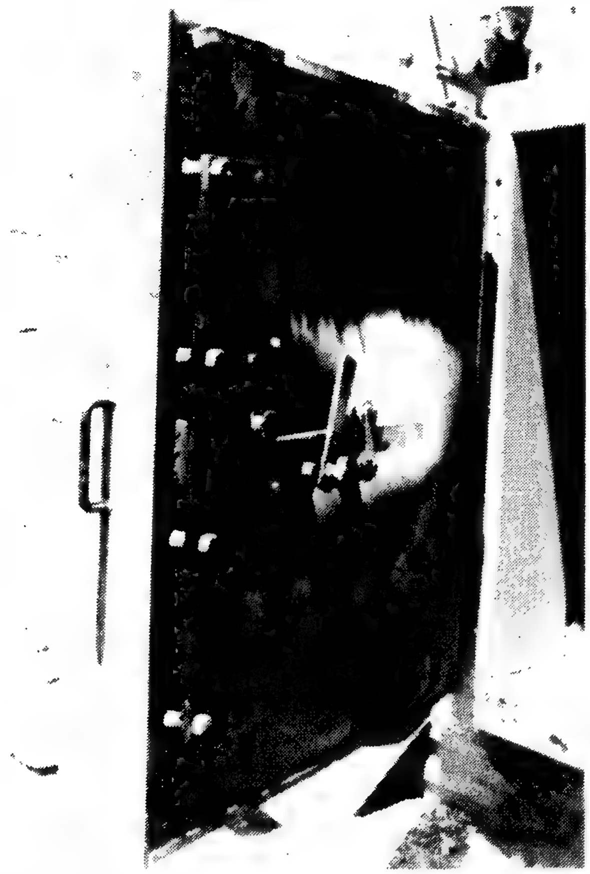
Photograph No 22
The reinforced concrete sample after the simulated attack.

Photographs No 23 and 24
The ASP sample after the
same simulated attack.
Note the localized damages.

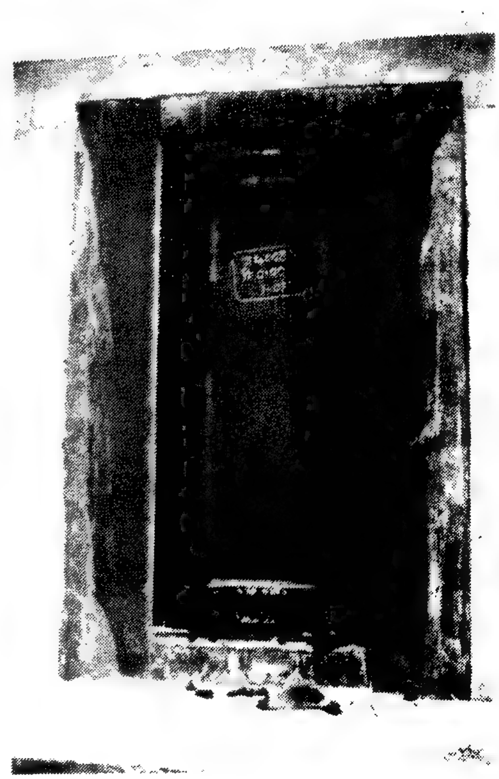




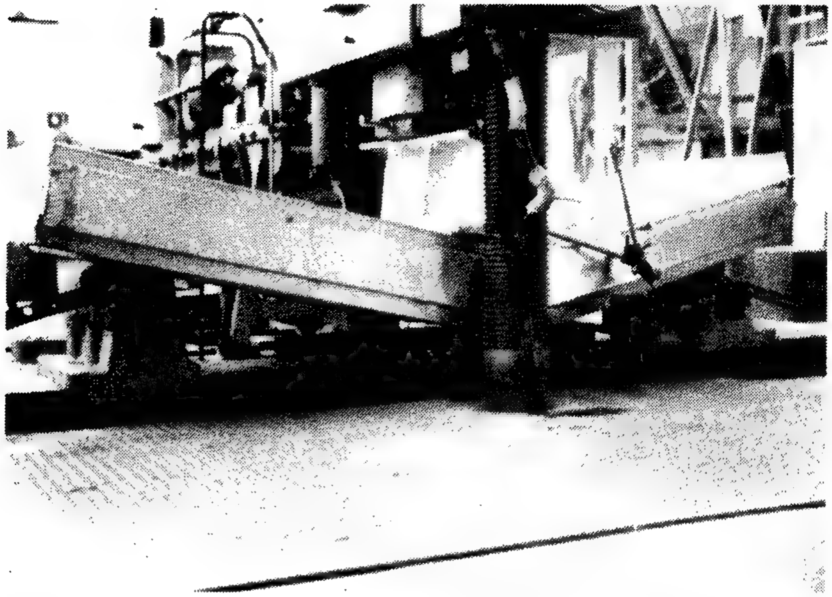
Photographs No
25, 26 and 27
Samples of ASP
walls after
simulated attacks



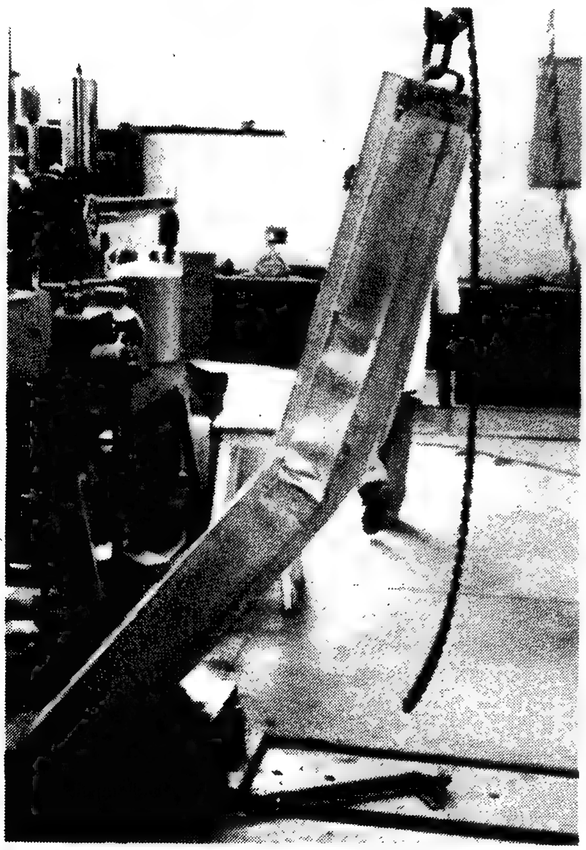
Photograph No 28
An EXP door remains operational after an attack



Photographs No 29 and 30 The front and rear of an EXP door sample after a simulated attack



Photographs No 31, 32 and 33
An ASP wall unit during and after a static load test



## GENERAL QUESTIONS

QUESTION Who markets the system in the U.S.A.?
ANSWER Innovative Military Technologies, Inc., 60 East 42nd Street New York, New York, telephone (212) 599-2030 - has the exclusive license.

QUESTION Is the system patented in the U.S.A.?
ANSWER Yes, the system is fully patented in the U.S.A.

QUESTION Who is the inventor and developer of the ASP System?
ANSWER Lt. Colonel Y. Yerushalmi, a professional engineer, invented and developed the system. He is the founder and director of YY Ltd. Until 1979 he was the head of protective structures branch of the IDF Corps of Engineers.

QUESTION When was the system developed?
ANSWER During 1980-1981. The first weapon test (air-bombs) was done in March, 1981 by the IDF.

QUESTION Why the name "ASP"?
ANSWER The name stands for Agan Steel Panels.

QUESTION Do you know of any similar system?
ANSWER As far as we know, a similar system does not exist.

QUESTION Why was the ASP System developed?
ANSWER There was a need for a new construction system specifically developed for protective structures, since the use of reinforced concrete became very expensive to meet higher levels of protection. The ASP System could meet those higher protective requirements in more effective and economic ways.

QUESTION Is the ASP System still under research and development?
ANSWER The system is a new construction technique, which was first introduced about 5 years ago. Many tests were done and certainly more will be done. There is a combined R & D program for the next two years. About 100 different projects utilizing the ASP System have been successfully completed. A lot of practical experience has been gained.

QUESTION Is the ASP a "walling system" only?
ANSWER No, the ASP system can be used to provide the composite of steel-concrete for walls, roof slabs, beams, and columns. Only the foundation is constructed in the "standard manner" for reinforced concrete (RC).

QUESTION What is the average cost of the ASP System compared to standard RC designs?
ANSWER A savings of at least 30% of constructions costs can be realized over reinforced concrete, utilizing the ASP System. This statement is applicable to single walls, sandwich walls and buildings constructed from single sandwich walls.

QUESTION Can the ASP System be used for multi-story buildings?

ANSWER Yes, the system can be designed and constructed for multi-story buildings. Three and four story ASP buildings have been constructed. One example is a computer center with three stories (20' each) with floor area of 85,000 sq. ft.

QUESTION Can the ASP System be used for underground structures?

ANSWER Yes, the system can be designed and constructed below ground level. A number of underground military installations have been constructed utilizing the ASP System.

QUESTION What are some of the capabilities of the ASP System?

ANSWER The ASP System is designed to withstand the effects of a large number of weapons, such as rockets, car bombs, limpit mines, high explosive charges and conventional air bombs. A number of tests using various weapons have been conducted. In each instance, the ASP System has been proven effective to withstand the weapon.

QUESTION What are the advantages of the ASP System?

ANSWER There are many advantages of the ASP System over conventional reinforced concrete. For example:

1. For a specified level of protection, approximately one-half thickness of the ASP System is equal to the full thickness of RC.

2. ASP provides reinforcement, formwork and anti-spalling plate as inherent to the system.

3. ASP precludes crack propagation and thus "localizes" the damage of the weapon's effect.

4. The ASP is quickly and easily assembled and erected and does not require skilled labor for form or steel work.

5. ASP is from 30% to 50% cheaper than the equivalent RC alternative.

6. The finished surface of ASP can be faced like RC, but also can be painted and thus is aesthetically more pleasing and acceptable than bare concrete.

QUESTION What are the industrial applications of the system?

ANSWER Any project designed to protect against accidental explosion should utilize the ASP system. Many explosives factories, ammunition magazines and ammunition storage facilities already have been built using the ASP System.

QUESTION Do you have a U.S. factory to manufacture the panel?

ANSWER Yes. A U.S. cold rolling (cold forming) manufacturing factory has been licensed by IMT to manufacture all types of ASP panels. ASP panels will be available in August, 1986.

QUESTIONS CONCERNING DESIGN AND ENGINEERING

QUESTION Can the system be compared to laced reinforced concrete - (concrete with a great deal of reinforcing rod)?

ANSWER The diagonal panels in the ASP act similar to laced reinforcement. A high degree of support rotation can be achieved in both systems. From a penetration resistance point of view, the ASP is superior since the laced concrete acts as standard reinforced concrete without spalling plates.

QUESTION How many weapon tests have been performed on the ASP System?

ANSWER About 15 different test series have been performed in three continents (including U.S.A.). A paper outlining the test results is available.

QUESTION What do you do to preclude corrosion?

ANSWER The steel panels are galvanized and painted. The joints between assembled panels is sealed.

QUESTION What are the dimensions of single walls?

ANSWER There are 3 basic wall thicknesses - 8", 10" and 12". Heights can vary up to 30'. The gage or thickness of ASP panes is 0.8mm, 1.00mm, or 1.2mm.

QUESTION Of the various configurations, what protection does the ASP single wall provide?

ANSWER The single wall ASP provides protection against a near miss (30 feet) of a mark 84 (2000 lb.) air bomb; a truck bomb (6,000 lbs of explosives) 30 feet away; a 500 lb car bomb (10 feet away); and direct hit of armour piercing projectiles up to 20 mm.

QUESTION What is the equivalent RC wall?

ANSWER Equivalent protection to the single ASP wall will be provided by a RC wall which is 2-3 times thicker

QUESTION Why does the ASP System provide such high resistance to penetration?

ANSWER The ASP section has a number of characteristics which make the system effective against penetration. They include:---

1. A continuously connected, well anchored, anti-spalling plate.

2. A reduced impact crater size due to actions of the back and the lacing plates.

3. Confinement of the concrete in wall sections formed by the external panels and the lacing liner.

4. Breakup and deflection of force vectors along surfaces created by the lacing panels.

QUESTION What is unique in the single ASP wall section?

ANSWER The use of relatively thin and flexible sections with high resistance to penetration and ability to absorb blast energy due to flexure mechanism. Support reaction is also low due to section flexibility. RC sections are relatively thick (for penetration resistance) and therefore very rigid. Support reaction is high and shear instead of flexible. Failure results.

QUESTION What type weapon does the sandwich wall configuration protect against?

ANSWER The sandwich wall protects against:

1. Direct hits of RPG7 rockets,
2. Direct hit of 122 mm KATUSHA rocket,
3. Near miss (10ft) of Mark 83 (1000 lb) bomb,
4. Truck bomb (10,000 lbs) 30ft away,
5. Car bomb (500 lbs) in "almost" contact,
6. Placed charge of 60 lbs.

QUESTION Are the dimensions of sandwich walls fixed?

ANSWER No. The sandwich wall consists of two parallel ASP walls separated by a void space. A standard sandwich wall consists of an 8" ASP wall, a 16" void space and another 8" ASP wall for a sandwich wall thickness of 32". The void space may be filled with a material to provide a specified level of protection (material such as sand, crushed rock, etc.). Sandwich walls may vary in thickness, but generally are from 24" to 48" thick.

QUESTION What is the alternative RC wall to the standard ASP sandwich construction?

ANSWER From a protection point of view, there is not a feasible alternative to the ASP sandwich construction. Sometimes a thick RC wall with well anchored steel plates may be considered as an alternative to the 32" ASP sandwich - (two 8" separate walls and 16" infill granite gravel).

QUESTION Did you try the system against terrorist rockets in U.S.?

ANSWER 5 RPG rockets were detonated on the 32" ASP sandwich wall. The average penetration was 16" (average penetration in RC is 32"). All the rockets were detonated on very small area, in order to assess the effect of repeated hits in a localized area. The same results cannot be achieved in RC due to crack propagation after first shock and to the larger impact crater. The test was conducted by the Naval Surface Weapons Center at Ft. A.P. Hill

QUESTION Why does the sandwich ASP section have high resistance against penetration of hollow (shaped) charge munitions?

ANSWER The two separate walls with infill granite material is the ideal layered section which is optimal against the

hollow charge jet. Granite gravel is by itself an ideal material to resist and dispurse the jet. In addition, the steel panel prevents spauling on the backside of the wall.

QUESTION Why does the sandwich ASP section have high resistance against localized blast effects of bombs or car bombs?

ANSWER The ASP sandwich consists of two separate, very flexible walls with an ideal shock absorbing infill layer between them. The second wall has a high support rotation without local shear or spall.

QUESTION Is the sandwich ASP wall economical?

ANSWER The ASP sandwich wall provides a very economic construction to deal cost effectively with hollow charge weapons or to absorb blast shock.

QUESTION Who will design the ASP system?

ANSWER A team with world known design specialists in the field of protective structures or anti-terrorist projects. This team has practical experience in the detail design cost estimating and bidding with the ASP system.

QUESTION Do you have practical experience in design and construction against car bombs?

ANSWER Yes. We have hardened existing facilities and constructed new facilities using the ASP System designed to withstand the effects of car bombs. Among the projects are hardening of transmitter stations, hardening of transformers, hardening of high rise buildings and construction of new computer centers.

QUESTION What would have been the effect of the car bomb in Beirut if the building had been made using the ASP System?

ANSWER We can state without question that the ASP building would not have collasped.

QUESTION Does the ASP System include doors?

ANSWER Doors designed to the same level of protection will be introduced with the ASP System. There are Blast and Fragment resistant doors equivalent to ASP single walls. There are Membrane type doors equivalent to the protection supplied by the ASP sandwich walls.

QUESTION Does the ASP System provide "EMP" shielding?

ANSWER The system has "built in" EMP shielding and self grounding characteristics.

QUESTION What finishes can be applied on the ASP System?

ANSWER Any finish material applicable to RC can be used on the ASP System. From practical experience, we have learned that smooth paint on the panels combined with a canapy is aesthetically pleasing. A rough finish which covers the vertical ribs is less attractive.

QUESTION What is the insulation capabilities of the system in ASP building?

ANSWER The insulation characteristics of the single wall is like RC, relatively poor. The insulation capability of the sandwich wall is relatively high.

QUESTION What is the fire rating of the ASP roof slab?

ANSWER The ASP slab has a two hour fire rating due to the thickness of the slabs and the negative reinforcement needed for the dynamic response.

QUESTION Do you have dynamic analysis for the ASP system?

ANSWER The resistance function of the single ASP wall is computed based on static flexure tests. This resistance function is introduced into the dynamic response model (single or multi degree of feeedom). Papers describing dynamic analysis of single and sandwich walls are available. Design examples are also available.

## QUESTIONS CONCERNING CONSTRUCTION OF THE ASP SYSTEM

QUESTION What supports or bracing is needed for wall construction?

ANSWER The walls are "self-supported" and can be constructed without any scaffolding. Nominal supports are required for roof slabs. ASP buildings with more than 1 floor are constructed without the use of scaffolding or supports.

QUESTION Do you have detailed specifications?

ANSWER Yes, detailed specifications and an erection manual are available.

QUESTION Is special knowhow required to perform an "ASP Job"?

ANSWER No, any civil contractor can bid for an ASP job. Detailed design and specifications are all that is needed.

QUESTION Speed of erection compared to RC?

ANSWER Erection of the ASP System (walls and slabs) is about five times quicker than compared to standard reinforced concrete for a like building.

QUESTION Is skilled labor or any special equipment required for ASP construction?

ANSWER Unskilled labor can be used without any special equipment.

QUESTION How are the ASP panels delivered to the site?

ANSWER The panels are supplied in bundles, direct from the factory. The panels are cut and marked according to the designed sheeting schedule.

QUESTION How many types of panels are in a typical project?

ANSWER The designer will make every effort to design a project using one type of external panel (for example - the entire project will be made of single 10" walls or sandwich walls with 10" walls). In this case, we will have one type of external panel and one type of diagonal panel (length of panels according to structure geometry). Non-standard panels are the corner elements (90 degree bend of a standard panel), cover plates and angles (kickers).

QUESTION Is the ASP System flexible so it can be constructed in various geometrics and dimensions?

ANSWER Almost any shape is possible and easy to construct, compared to reinforced concrete. For example, a building with round ASP walls and roof slab is simple to erect.

QUESTION How are openings made in the ASP building?

ANSWER Small openings (width of 1-2 panels) will be made after the erection of the panels and before concreting. The panels will be cut on site and blinding frame will be installed. Big openings (doors, windows) will be part of the sheeting schedule and the frames will be erected with the panels.

QUESTION How is concrete poured into the ASP walls?

ANSWER 4500 P.S.I. concrete with 6-7" slump is poured in layers. No supports are needed. No vibration is needed. Concreting in horizontal layers can be stopped and cold horizontal joint is "automatically achieved". Highest recommended lift is 30" ft.

QUESTION Which type of foundations will be used in the ASP?

ANSWER Standard RC or raft foundation will be used. Foundation on piles can be used, but is not recommended in any case of protective structures.

QUESTION Which reinforcement will be used in the ASP System?

ANSWER The ASP panels serve as reinforcement. Standard reinforcement will be used for any connection detail, such as footing to wall or wall to roof slab. In roof slabs, negative reinforcement will be introduced.

QUESTION Can any civil contractor bid on an ASP job?

ANSWER Any contractor can utilize the ASP System without any difficulty. The "learning curve" of the system is relatively short.

QUESTION Do you have movable walls?

ANSWER The ASP System is ideal for movable elements due to its weight advantage, compared to RC alternatives. We have movable single walls (T-elements) with male-female connection. We have also movable "strong rooms" with standard dimensions. A complete installation can be designed and constructed with pre-fabricated elements.

QUESTION Which components are supplied to the site besides the ASP panels?

ANSWER All the doors, windows, frames, etc., which are to be erected with the ASP panels.

INNOVATIVE MILITARY TECHNOLOGIES
PROPRIETARY

PATENTED
REVERSE ENGINEERING UNAUTHORIZED

# TESTS PERFORMED

ON THE

# THE ASP WALLING SYSTEM

UPDATE MAY 1985 FOR

INNOVATIVE MILITARY TECHNOLOGIES, INC

SUITE 2530, 60 EAST 42nd STREET, NEW YORK

[illegible]

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# 1. INTRODUCTION

1.1 The purpose of this document is to describe briefly dynamic and static tests of the ASP walling system.

1.2 There are five different categories of tests as follows;

a. AIR BOMBS : Single wall or standard box structure to withstand near miss of airbombs.

b. ROCKETS : Layered or sandwich wall to withstand direct hit of hollow charge and HE rockets.

c. CHARGES : Single walls to withstand place charges.

d. DOORS : Tests of doors.

e. STATIC TESTS : Static tests to predict the resistance function of the ASP walling system under blast loads.

## 2. AIR BOMB TESTS

2.1 TEST NUMBER : 1 ,YEAR : 1981 , FIG "1" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system under near miss of MK-82.

TEST SAMPLE : ASP prefabricated box structure with the following standard dimensions:

Length = 10' , Width = 10' , Hight = 7'

Wall thickness = 10", Roof thickness = 10", floor = 6"

Sheet thickness, Wall = 0.022" ,Diagonal = 0.016",

Roof = 0.022" .

Concrete : 5000 psi, Conventional floor.

TYPE OF WEAPON : GP, MK-82, Tritonal fill.

MUNITION ORIENTATION : Wall "1" of the standard box structure parallel to the central axis of the bomb. (90 degrees polar angle).

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the tested wall. No spalling or perforation. Depth of craters up to 2".

CONCLUSIONS : 10" ASP wall section can be used for near miss of single MK-82, the expected damage is very local and the wall will remain structurally intact after the "attack".

2.2 TEST NUMBER : 1A ,YEAR : 1981 , FIG "1" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system under repeated near miss of MK-82.

TEST SAMPLES : The same wall of the same standard box described in chapter 2.1.

TYPE OF WEAPON : GP, MK-82, Tritonal fill.

MUNITION ORIENTATION : Wall "1" of the standard box structure parallel to the central axis of the bomb. (90 degrees polar angle).

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the tested wall. No spalling or perforation. More local damage was developed without significant increase in the depth of the craters.

CONCLUSIONS : 10" ASP wall section can be used for repeated near miss of MK-82 without perforation or spalling of the wall section.

2.3 TEST NUMBER : 1C ,YEAR : 1981 , FIG "1" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system under near miss of 1100 lbs GP bomb.

TEST SAMPLE : Wall "2" of the standard box described in chapter 2.1.

TYPE OF WEAPON : 1100 lbs GP high drag bomb. The fragments generated by this bomb are much heavier then the fragments of the MK-82 or the MK-83.

MUNITION ORIENTATION : Wall "2" of the standard box structure parallel to the central axis of the bomb. (90 degrees polar angle).

TEST PROCEDURE : Single static detonation.

TEST RESULTS :Good fragment distribution on the tested wall. No spalling or perforation. Depth of craters up to 3" with local bulge of the inner sheet.

CONCLUSIONS : 10" ASP wall section can be used in structure designed for near miss of 1100 lbs GP bombs. The ASP walling system has high resistance to heavy fragments.

2.4 TEST NUMBER : 2 ,YEAR : 1981 , FIG "2" IN APPENDIX "A"

PURPOSE OF TEST : To assess the dynamic response of

ASP buried structure under ground shock waves.

TEST SAMPLES : Wall "3" of the standard box described in chapter 2.1. The box is semi-buried as illustrated fig.2 of appendix "A".

TYPE OF WEAPON : 1100 lbs GP air bomb, "semi-confined".

MUNITION ORIENTATION : Wall "3" of the standard box structure parallel to the central axis of the bomb. The bomb and the wall were covered with local soil.

TEST PROCEDURE : Single detonation of the buried bomb.

TEST RESULTS : Soil cover was completely exposed from the tested wall which was deep inside the bomb crater. Box movement was about 4".
No spalling or plastic deformation of the wall section was found. Similar tests of reinforced concrete boxes at scaled distance of about 2 ft/lbs^1/3 indicated medium or heavy damage with spalling.

CONCLUSIONS : 10" ASP wall section can be used for buried structure designed for near miss of 1100 air bombs.

2.5 TEST NUMBER : 2A ,YEAR : 1981 , FIG "2" IN APPENDIX "A"

PURPOSE OF TEST : To assess the ductility and the

dynamic response of the ASP walling system.

TEST SAMPLES : Wall "3" of the standard box described in chapter 2.1. The box is semi-buried as illustrated fig.2 of appendix "A".

TYPE OF WEAPON : 1100 lbs GP air bomb,"fully confined".

MUNITION ORIENTATION : Wall "3" of the standard box structure parallel to the central axis of the bomb. The bomb and the wall were covered with local soil.

TEST PROCEDURE : Single detonation of the buried bomb.

TEST RESULTS : Soil cover was completely exposed from the tested wall which was deep inside the bomb crater. Box movement was about 40".
Very heavy plastic deformation of the wall section was found. The relative displacement was about 1/20 without breaching or spalling of the section !!!!
Similar tests of reinforced concrete boxes at scaled distance of about 2 ft/lbs^1/3 indicated heavy damage with spalling.

CONCLUSIONS : The ASP sections are very ductile and can develop a relatively very large plastic displacement under blast loads.

2.6 TEST NUMBER : 3 ,YEAR : 1982 .

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for near miss of airbombs.

TESTED CRITERIA : GP MK-83 (1000 lbs bomb) at 33' distance from the structure.

TEST SAMPLE : ASP prefabricated box structure with the following standard dimensions:

Length = 7.5' , Width = 5' , Hight = 6.6'

Wall thickness = 10", Roof thickness = 10", floor = 10"

Sheet thickness, Wall = 0.032" ,Diagonal = 0.024", Roof = 0.032" .

Concrete : 5000 psi, Conventional floor.

TYPE OF WEAPON : GP, MK-83, Torpex fill.

MUNITION ORIENTATION : Wall "1" of the standard box structure parallel to the central axis of the bomb. (90 degrees polar angle).

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the tested wall. No spalling or perforation. Depth of craters up to 2".

CONCLUSIONS : 10" ASP wall section can be used for near miss of single MK-83, the expected damage is very local and the wall remained structurally intact after

the "attack".

2.7 TEST NUMBER : 4 ,YEAR : 1985 , FIG "3" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for near miss of airbombs.

TESTED CRITERIA : GP MK-84 (2000 lbs bomb) at 33' distance from the structure.

TEST SAMPLE : ASP prefabricated box structure with the following standard dimensions:
Length = 7.5' , Width = 5' , Hight = 6.6'
Wall thickness = 10", Roof thickness = 10", floor = 10"
Sheet thickness, Wall = 0.032" ,Diagonal = 0.024",
Roof = 0.032" .
Concrete : 5000 psi, Conventional floor.

TYPE OF WEAPON : GP, MK-84, H-6 fill.

MUNITION ORIENTATION : Wall "2" of the standard box structure at 75 degrees polar angle.

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the tested wall. No spalling or perforation. Depth of craters up to 4-6". measured weight of critical fragments was 7 OZ with velocity of 7250 ft/sec.

This fragment will penetrate about 20" of reinforced concrete.

CONCLUSIONS : 10" ASP wall section can be used for near miss of single MK-84 at distance of 33', the expected damage is very local and the wall remained structurally intact after the "attack".

2.8 TEST NUMBER : 4A ,YEAR : 1985 , FIG "3" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for near miss of airbombs.

TESTED CRITERIA : GP MK-84 (2000 lbs bomb) at 33' distance from the structure.

TEST SAMPLE : Wall "1" of the previous box structure.

TYPE OF WEAPON : GP, MK-84, H-6 fill.

MUNITION ORIENTATION : Wall "2" of the standard box structure at 85 degrees polar angle.

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the tested wall. No spalling or perforation. Depth of craters up to 4-6" with local plastic bulging of the inner sheeting. measured weight of criteria fragments was 7 OZ with velocity of 7250 ft/sec.This fragment

will penetrate about 20" of reinforced concrete.

CONCLUSIONS : 10" ASP wall section can be used for near miss of single MK-84 at distance of 33', the expected damage is very local and the wall remained structurally intact after the "attack".

2.9 TEST NUMBER : 5 ,YEAR : 1985 , FIG "4" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for near miss of airbombs.

TESTED CRITERIA : GP MK-84 (2000 lbs bomb) at 33' distance from the structure.

TEST SAMPLE : ASP prefabricated sandwich wall structure

with the following standard dimensions:

Length = 10' , Width = 4' , Hight = 7'

Walls thickness = 8", Sheet thickness = 0.32",Diagonal

sheet thickness = 0.022".Thickness of middle layer =
28"

"Filling material" in middle layer - Air.

Concrete : 5000 psi, Conventional floor

TYPE OF WEAPON : GP, MK-84, H-6 fill.

MUNITION ORIENTATION : Front wall of the sandwich structure at 75 degrees polar angle.

TEST PROCEDURE : Single static detonation.

TEST RESULTS : Good fragment distribution on the front wall of the sandwich sample. No spalling or perforation. Depth of craters up to 4-6" with local plastic bulging of the inner sheeting. measured weight of criteria fragments was 7 OZ with velocity of 7250 ft/sec. This fragment will penetrate about 20" of reinforced concrete.

CONCLUSIONS : 8" ASP wall section can be used for near miss of single MK-84 at distance of 33', the expected damage is very local and the wall remained structurally intact after the "attack".

## 3. HOLLOW CHARGE AND HE ROCKET TESTS

3.1 TEST NUMBER : 6 ,YEAR : 1982 , FIG "6" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for against direct hit of R.P.G 7.

TESTED CRITERIA : Direct hit of R.P.G 7

TEST SAMPLE : ASP prefabricated sandwich wall structure

with the following standard dimensions:
Length = 10' , Width = 32" , Hight = 7'
Walls thickness = 8", Sheet thickness = 0.32",Diagonal sheet thickness = 0.22". Thickness of middle layer =16"
"Filling material" in middle layer - 2" granite gravel.

Concrete : 5000 psi, Conventional floor

TYPE OF WEAPON : R.P.G 7

MUNITION ORIENTATION : Front wall of the sandwich structure normal to the firing line.

TEST PROCEDURE : 4 rocket fired from 600'.

TEST RESULTS : No spalling or perforation. local plastic bulging of the external sheeting of the back 8" wall.

CONCLUSIONS : The ASP sandwich or layered sections can used in structures designed to direct hit of R.P.G 7

3.2 TEST NUMBER : 7 ,YEAR : 1982 , FIG "5" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capabilities of the ASP walling system for against direct hit of HE 2.75" rockets.

TESTED CRITERIA : Direct hit of HE 2.75" rocket.

TEST SAMPLE : ASP prefabricated sandwich wall structure with the following standard dimensions:

Length = 10' , Width = 24" , Hight = 7'

Walls thickness = 8", Sheet thickness = 0.32",Diagonal sheet thickness = 0.022".Thickness of middle layer = 8".

"Filling material" in middle layer - Air.

Concrete : 5000 psi, Conventional floor

MUNITION ORIENTATION : Front wall of the sandwich structure at 90 to firing line.

TEST PROCEDURE : Rocket fired from aircraft.

TEST RESULTS : No spalling or perforation of the front wall. Very local craters.

CONCLUSIONS : 8" ASP single wall can be used in structures designed to direct hit of HE 2.75" rocket.

4. PLACED CHARGES ON SINGLE WALLS

4.1 TEST NUMBER : 8 ,YEAR : 1981 , FIG "7" IN APPENDIX "A"

PURPOSE OF TEST : To assess the capability of the ASP walling system against placed charges.

TEST SAMPLES : Prefabricated 10" single ASP wall. External sheet thickness = 0.032", Diagonal sheet thickness = 0.022". Reinforced concrete sample with section thickness of 16".

TYPE OF CHARGE : 6.6 LBS T.N.T

MUNITION ORIENTATION : Charge was placed directly on wall's center in order to prevent edge effects.

TEST PROCEDURE : Electric detonation of the charge,

fuse at the "back" of the charge.

TEST RESULTS : Heavy local deformation and bulging of back sheet of the ASP wall without spalling.
Heavy spalling of the reinforced concrete wall.

CONCLUSIONS : 10" ASP walling section can be used for for walls designed to placed charge of 6.6 lbs T.N.T
The ASP response to place charges is superior compared to reinforced concrete sections. 10" of ASP system performed much better compared to 16" concrete section.

4.2 TEST NUMBER : 9 ,YEAR : 1982 .

PURPOSE OF TEST : To assess the capability of the ASP walling system against placed charges.

TEST SAMPLES : Prefabricated 10" single ASP wall.
External sheet thickness = 0.032", Diagonal sheet thickness = 0.022". Prefabricated 8" single ASP walls with the same sheeting thicknesses. Prefabricated 12" single ASP walls with external sheets of 0.048" thick and diagonal sheets of 0.022".

TYPE OF CHARGES : 2.2 lbs PE.4, 3.75 LBS PE.4, Limped mine with 4.4 lbs T.N.T. The PE.4 plastic charge is similar to the C4. This plastic charges were shaped in the site to improve the breaching capability.

MUNITION ORIENTATION : Charges were placed directly on wall's center to prevent edge effects.

TEST PROCEDURE : Electric detonation of the charge, fuse at the "back" of the charge. 4 shape charges of 2.2 lbs,4 charges of 3.75 lbs and one mine were detonated.

TEST RESULTS : The purpose of this test was to calibrate the resistance of the various ASP sections to withstand "shape charges". This data is needed for design purposes of walls and door panels.

CONCLUSION : 8" and 10" ASP wall section can be used for walls designed against 2 lbs of shaped C4 charge. 12" ASP can be used for 3.75 C4 shaped charge and limped mine with 6.6 T.N.T not shape charge.

5. TEST OF DOORS

5.1 TEST NUMBER : 10 ,YEAR : 1981 , FIG "8" IN APPENDIX "A"

PURPOSE OF TEST : To assess the dynamic response of ASP blast and CBR proof door.

TEST SAMPLES : ASP blast and CBR proof door built into 10" prefabricated ASP wall section . The door was completely operational with locking mechanism. The door panel was made of 0.4" bent A36 steel plate with

horizontal bracing of 5" high I beams. No vertical bracing of the panel edges due to the plate bends.

TYPE OF WEAPON : High Explosive charges calculated to be equivalent to MK-82 and MK-83.

TEST PROCEDURE : Detonation of the two charges opposite the same door.

TEST RESULTS : The "MK-82" charge had minor effects on the door and therefor it was decided to proceed with the "MK-83" charge on the same door. After this explosion plastic deformation of the front plate was noticed between the horizontal bracing but not along the edges. The CBR protection remained intact. The locking mechanism remained operational. The reflected pressure was about 225 P.S.I at 4 MSEC.

CONCLUSIONS : The ASP blast and CBR proof door can be used for blast caused by near miss of MK-83.

5.3 TEST NUMBER : 11 ,YEAR : 1981 , FIG "8" IN APPENDIX "A"

PURPOSE OF TEST : To assess the dynamic response of ASP blast and fragment proof door under near miss of air bombs.

TEST SAMPLE : ASP blast and fragment proof door built into 8" prefabricated ASP wall section . The door was

completely operational with locking mechanism. The door panel was made of 0.4" bent A36 steel plate with horizontal bracing of 5" high I beams. No vertical bracing of the panel edges due to the plate bends. Back plate of 0.4" A36 steel plate with concrete fill.

TYPE OF WEAPON : MK-83 with H-6 fill.

TESTING CRITERIA : MK-83 , 33 FT away.

TEST PROCEDURE : Static detonation of the bomb on wooden stand.

MUNITION ORIENTATION : ASP wall section with the door parallel to the central axis of the bomb. (90 degrees polar angle).

TEST RESULTS : No penetration or spalling with local bulging of the back plate behind large craters. Plastic deformation of the front plate between the horizontal bracing but not along the edges. The locking mechanism remained operational. The reflected pressure was about 225 P.S.I at 4 MSEC.

CONCLUSIONS : The ASP blast and fragment proof door can be used for structured designed to near miss of GP-MK-83.

5.3 TEST NUMBER : 12 ,YEAR : 1981, FIG "9" IN APPENDIX A

PURPOSE OF TEST : To assess the capability of

space plate door panels against placed charges.

TEST SAMPLES : Door panels made of spaced A36 steel plates. Sample "A" with 0.4" plates at 5" distance. Sample "B" with 0.4" front plate and 1" back plate at 10" distance.

TYPE OF CHARGES : 6,6 AND 22 LBS of T.N.T.

MUNITION ORIENTATION : Charges were placed directly on door's center to prevent edge effects.

TEST PROCEDURE : 6.6 lbs charge was detonated on sample "A" and 22 lbs charge was detonated on sample "B".

TEST RESULTS : Heavy plastic deformation without breaching of the back plate in both tests.

CONCLUSION : The ASP space plates door can be designed for placed charges up to 22 LBS of T.N.T

5.4 TEST NUMBER : 13 ,YEAR : 1984, FIG "9" IN APPENDIX A

PURPOSE OF TEST : To assess the capability of "membrane" door panel under placed charge of 35 lbs of T.N.T.

TEST SAMPLES : Door panels made of curved A36 1.6" thick steel plate. 0.4" back plate and

wooden slipper between the the back and the curved plate. Thickness of door 22".

TYPE OF CHARGES : 35 lbs T.N.T

MUNITION ORIENTATION : Charge were placed directly on door's center to prevent edge effects.

TEST PROCEDURE : Single detonation of the charge.

TEST RESULTS : Heavy plastic deformation without breaching of the back plate.

CONCLUSION : The ASP curve plate door can be designed for placed charges up to 35 LBS of T.N.T

5.5 TEST NUMBER : 14 ,YEAR : 1985, FIG "9" IN APPENDIX A

PURPOSE OF TEST : To assess the capability of "membrane" door panel under placed charge of 55 lbs of C4.

TEST SAMPLES : Door panels made of curved A36 1.6" thick steel plate. 0.4" back plate with special mix between the the back and the curved plate. Thickness of door 28".
The door was casted into concrete wall.

TYPE OF CHARGES : 55 lbs C4.

MUNITION ORIENTATION : Charge were placed directly on

## 6. STATIC TESTS

### 6.1. TEST NUMBER : 15 ,YEAR : 1984 ,FIG "11" IN APPENDIX "A"

PURPOSE OF TEST : To establish the resistance function of the ASP function for routine design purposes.

TEST SAMPLES : 4 samples of 8" ASP wall panel. Length 6.6', width of two elements 32" and the other two elements 24". Thickness of external sheets 0.032" (A36 mild steel). Diagonal sheets 0.024" thick. Concrete 3500 P.S.I

TEST PROCEDURE : Standard bending test.

TEST RESULTS : All the elements had 13.5 degrees support rotation without failure of the plastic hinge. Normal reinforced concrete has 1-2 degrees possible support rotation without failure of the plastic hinge. Note - 13.5 degrees was the maximum clearance of the bending machine. The measured resistance function is in FIG 11 of appendix "A".

CONCLUSIONS : The fantastic ductility of the ASP system compared to standard reinforced concrete was proved in this test. The resistance function of the ASP walling system is available for routine design purposes.

door's center to prevent edge effects.

TEST PROCEDURE : Single detonation of the charge.

TEST RESULTS : Local plastic deformation without breaching of the back plate.

CONCLUSION : The ASP curve plate door can be designed for placed charges up to 55 LBS of C4.

5.6 TEST NUMBER : 14 ,YEAR : 1985, FIG "10" IN APPENDIX A

PURPOSE OF TEST : To assess the capability of "membrane" door panel under direct hit of RPG 7.

TEST SAMPLES : Door panels made of curved A36 1.6" thick steel plate. 0.4" back plate with special mix between the the back and the curved plate. Thickness of door 28".
The door was casted into concrete wall.

MUNITION ORIENTATION : Front plate of the door normal to firing line.
TEST PROCEDURE : R.P.G rocket fired from 220'.

TEST RESULTS : The R.P.G 7 jet did not penetrate through the special mix inside the doors.

CONCLUSION : The ASP curve plate door can be used in structure designed to direct hit of R.P.G.7

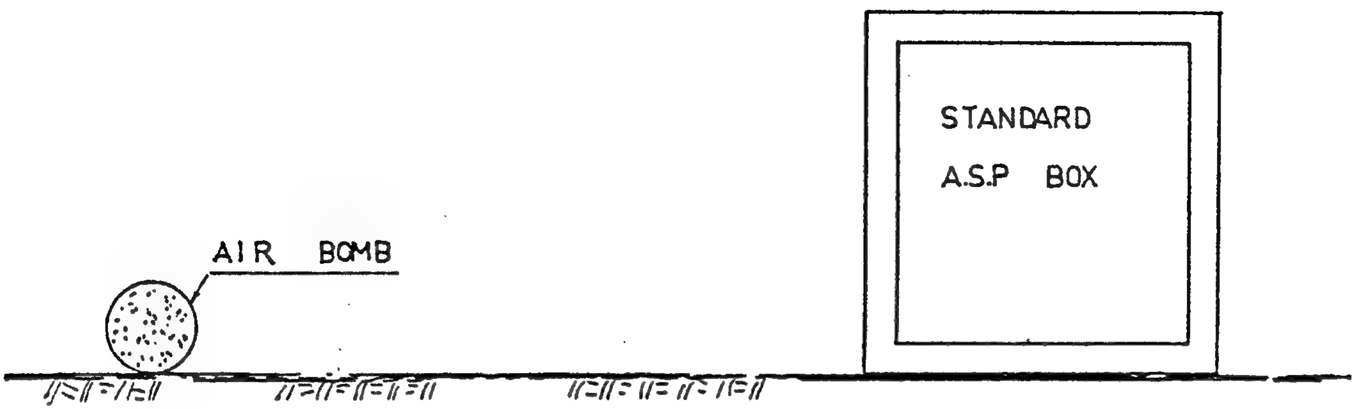


FIG. 1: NEAR MISS OF AIR BOMB

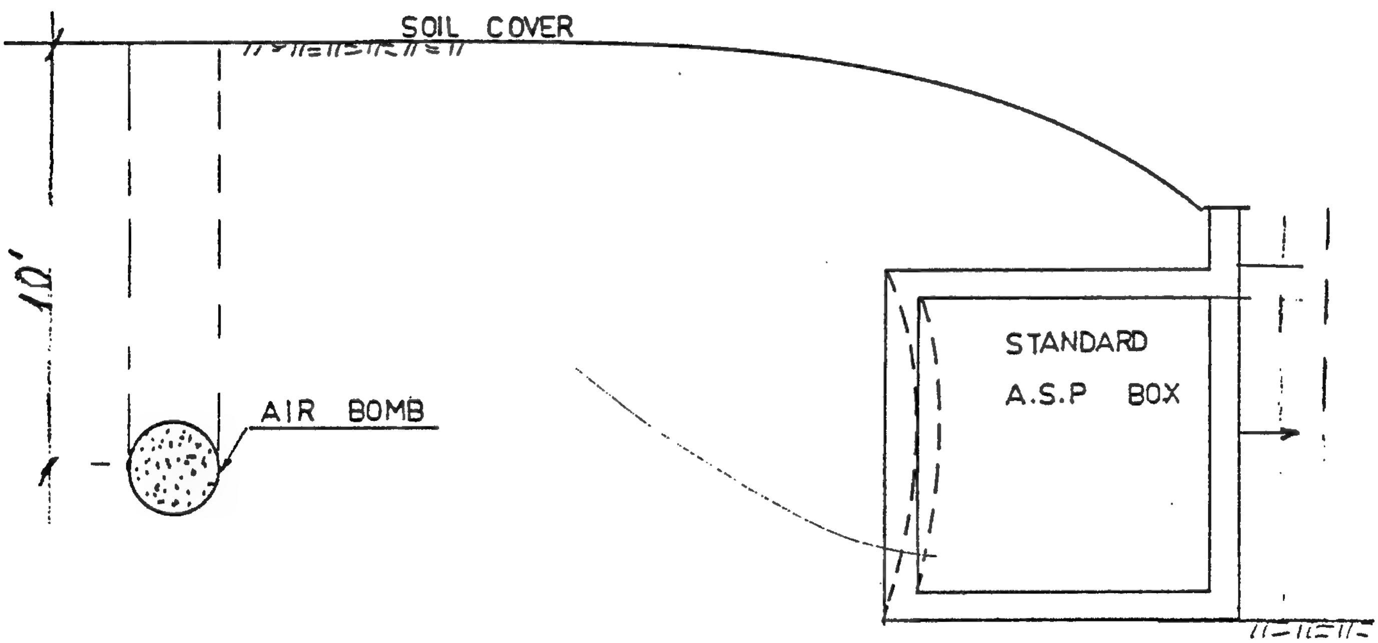


FIG. 2: SIMULATED OF AIR BOMB NEAR MISS ON BURIED STRUCTURE

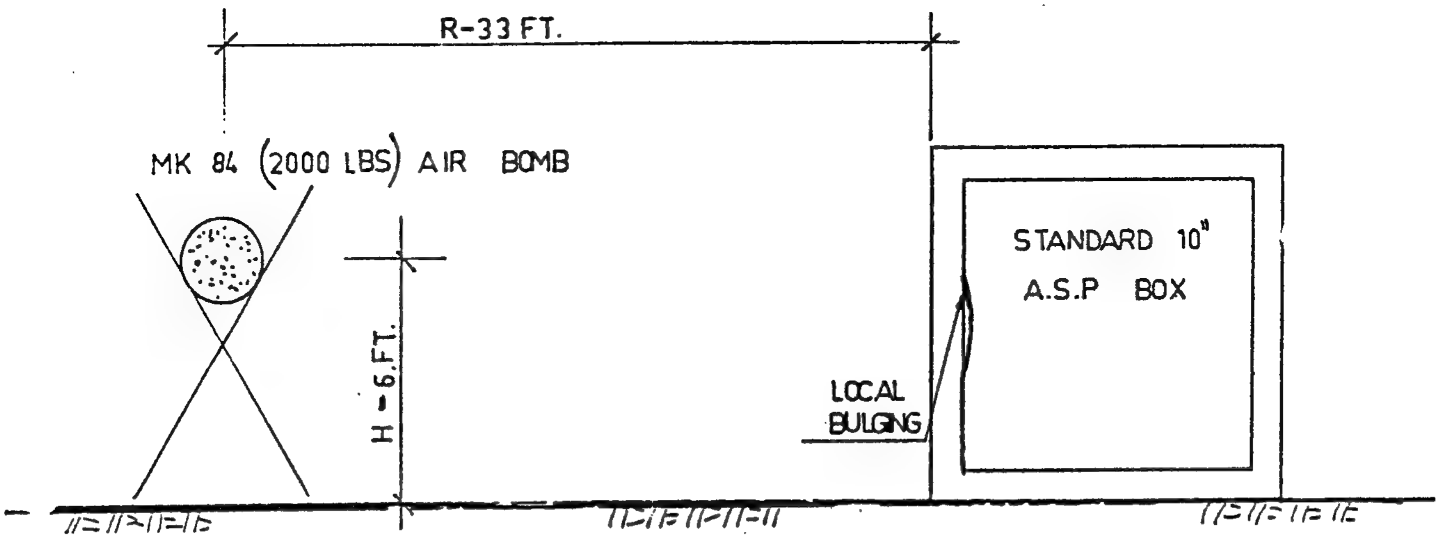


FIG. 3: NEAR MISS OF MK 84 TEST

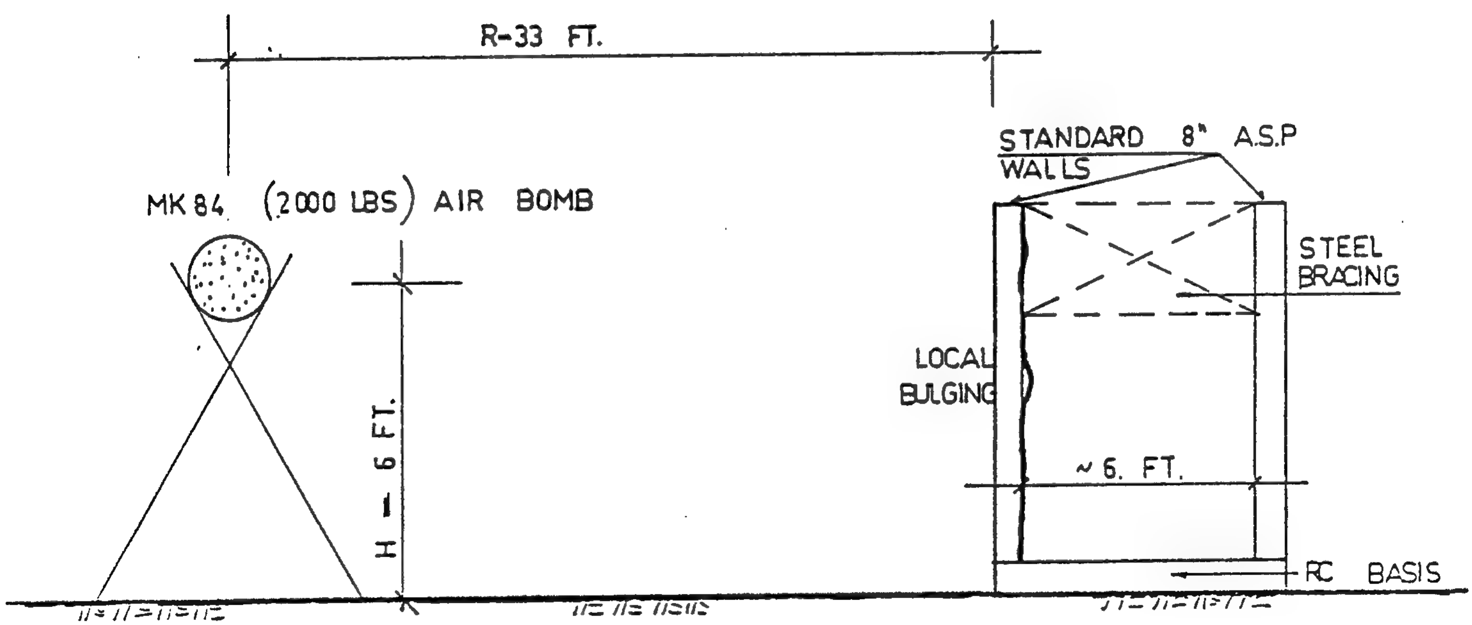


FIG. 4: NEAR MISS OF MK 84 TEST

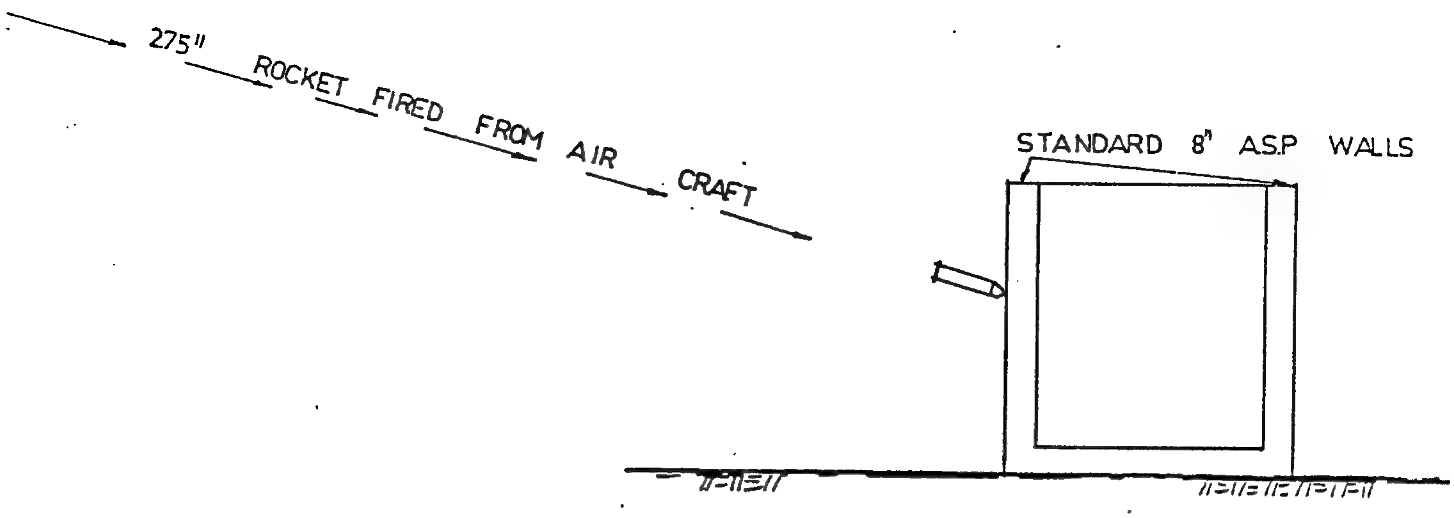


FIG. 5: DIRECT HIT OF 2.75" ROCKET

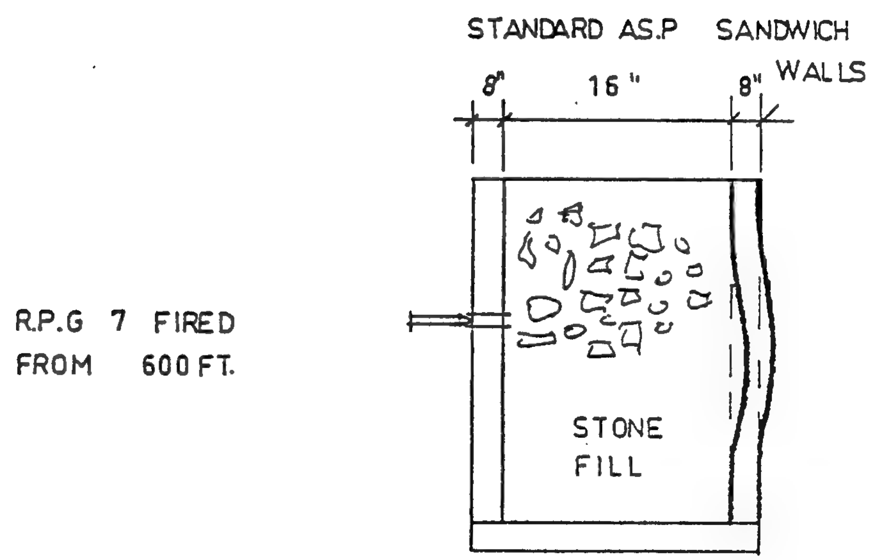


FIG. 6: DIRECT HIT OF RPG 7 ROCKETS

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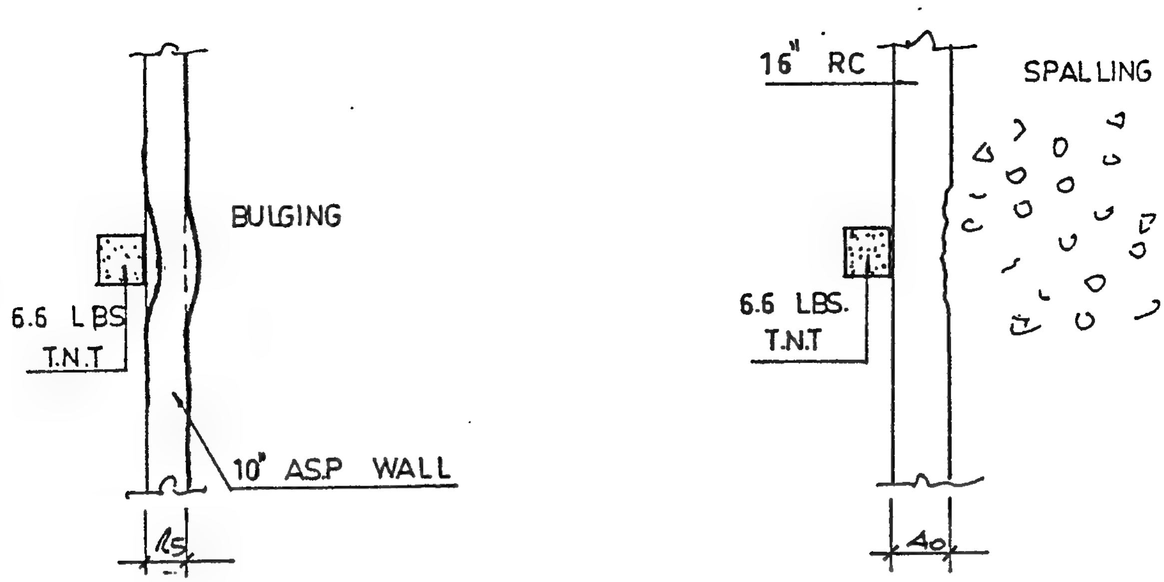



FIG. 7: PLACED CHARGE TESTS

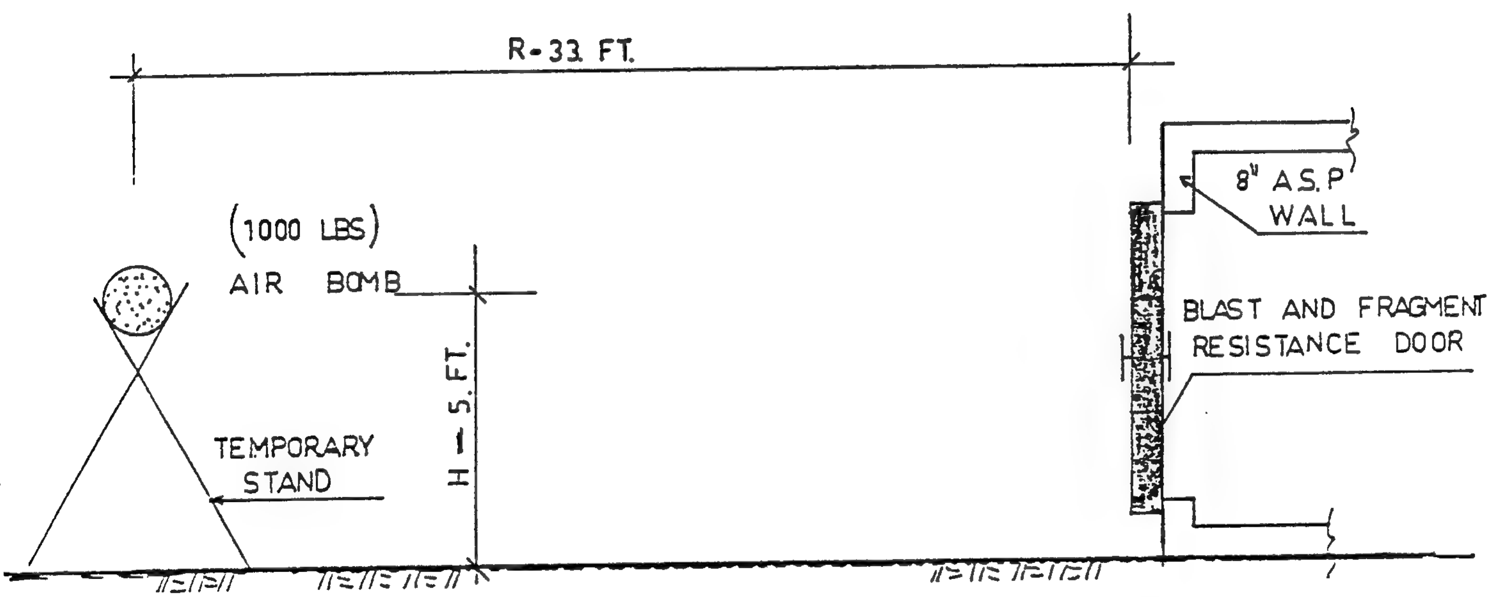



FIG. 8: BLAST AND FRAGMENT RESISTANCE DOOR TEST

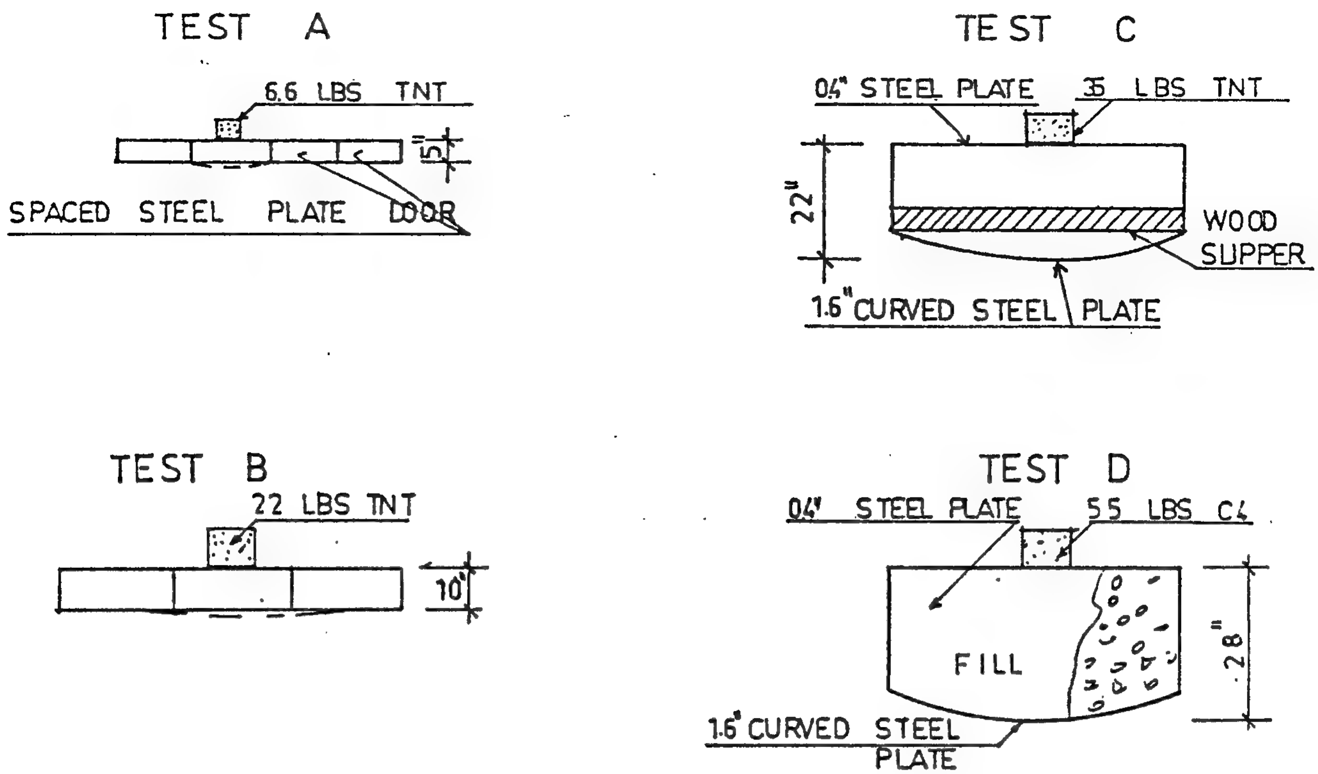



FIG. 9: PLACED CHARGE ON PROTECTIVE DOORS

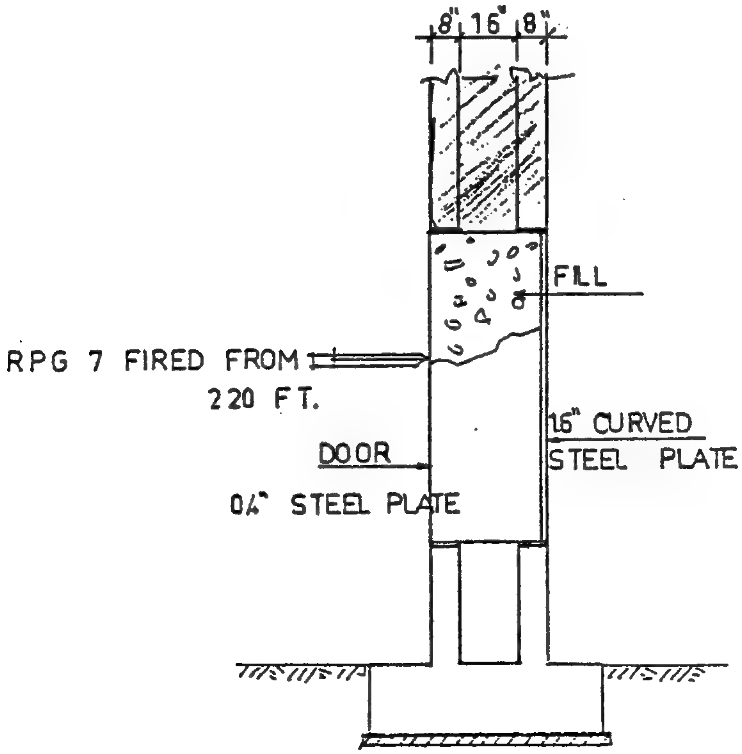



FIG. 10: RPG 7 ROCKET FIRED ON PROTECTIVE DOORS

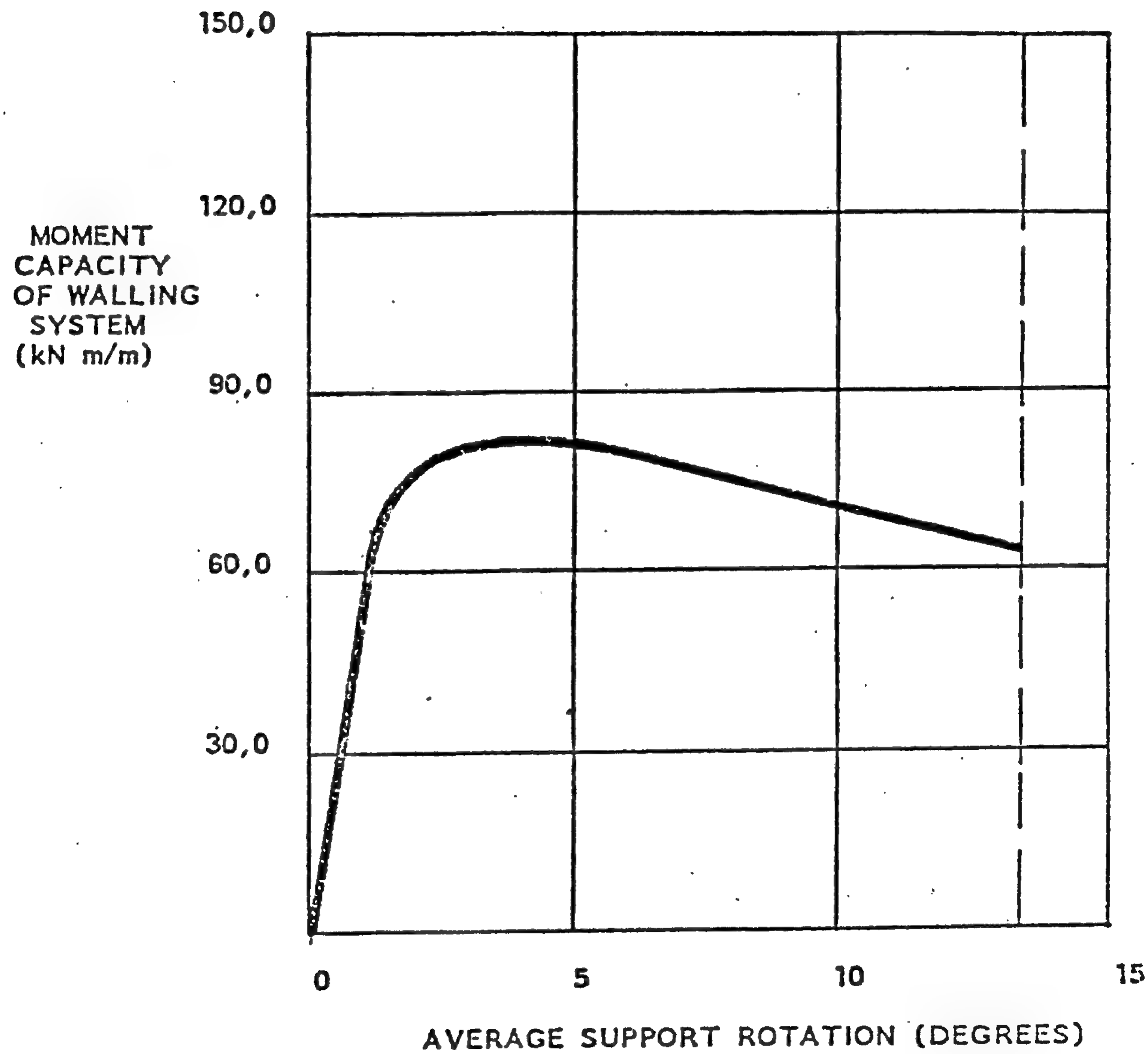



FIG 11: MOMENT-ROTATION RELATIONSHIP PER UNIT WIDTH OF 200mm THICK ASP WALLING WITH SHEETING IN THE SPAN DIRECTION.

CAPABILITIES DOCUMENT

PROTECTIVE STRUCTURES

# INNOVATIVE MILITARY TECHNOLOGIES

GENERAL

AREAS OF ACTIVITY

- HARDENING CONSULTANCY.
- EVALUATION OF WEAPON EFFECTS.
- THREAT SCENARIO AND PROPABILITY ANALYSIS.
- DETAILED DESIGN OF PROTECTIVE STRUCTURES.
- CIVILLIAN SHELTER DESIGN.
- DYNAMIC ANALYSIS.
- DOORS (BLAST/FRAGMENTS/GAS AND ANTI-EXPLOSIVE DOORS).
- AMMUNITION AND EXPLOSIVE MAGAZINES DESIGN.
- EXPLOSIVES, AMMUNITION AND CHEMICAL INDUSTRY FACILITIES.
- TESTING FACILITIES OF AMMUNITION AND EXPLOSIVES.
- EXPLOSIVE CHAMBERS DESIGN.
- FIELD AND PERMANENT FORTIFICATIONS
- URBAN-FIGHT TRAINING FACILITIES
- MILITARY ANTENA TOWERS,WATCH TOWERS AND BRIGDE DESIGN
- HARDENING OF NATIONAL KEY POINTS AGAINST ACTS OF TERROR
- DESIGN OF ANTI-EXPLOSIVE FACILITIES FOR AIRPORTS
- DESIGN OF HIGH RISE BUILDINGS AGAINST CAR BOMBS
- SPECIFIC PROTECTIVE REQUIREMENTS AND BUILDING CODES
- RESEARCH,DEVELOPMENT AND TESTING

SLIDE CORRECTION

If your in the design or planning stage or about to construct: call or write for details.

A licensed manufacturer of STA-WAL® systems

STA-WAL® is a Registered Trademark of
Marine Modules Incorporated
STA-WAL® Systems

SPECIFY

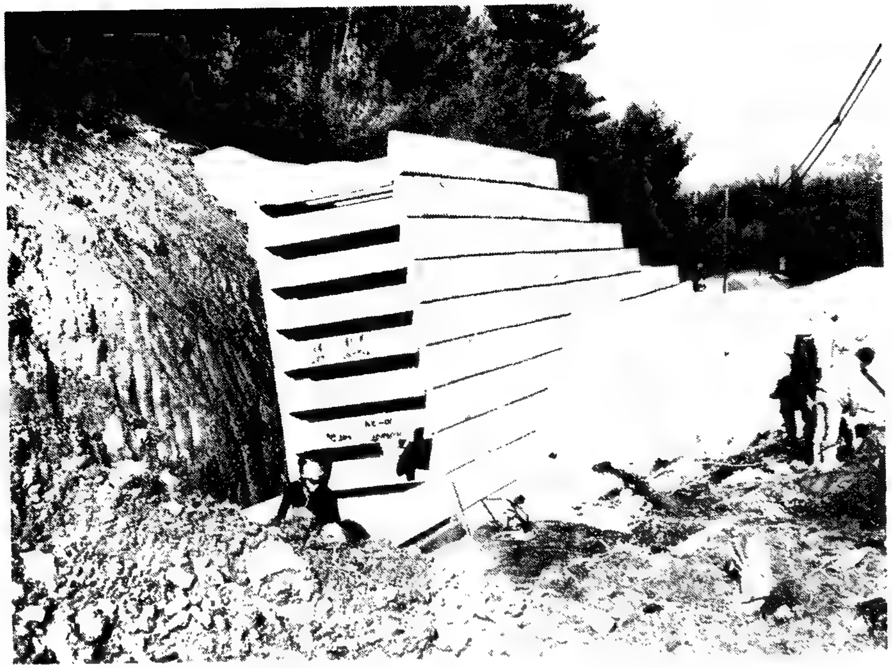
# STA-WAL®

## PATENTED PRECAST CONCRETE RETAINING WALL SYSTEMS

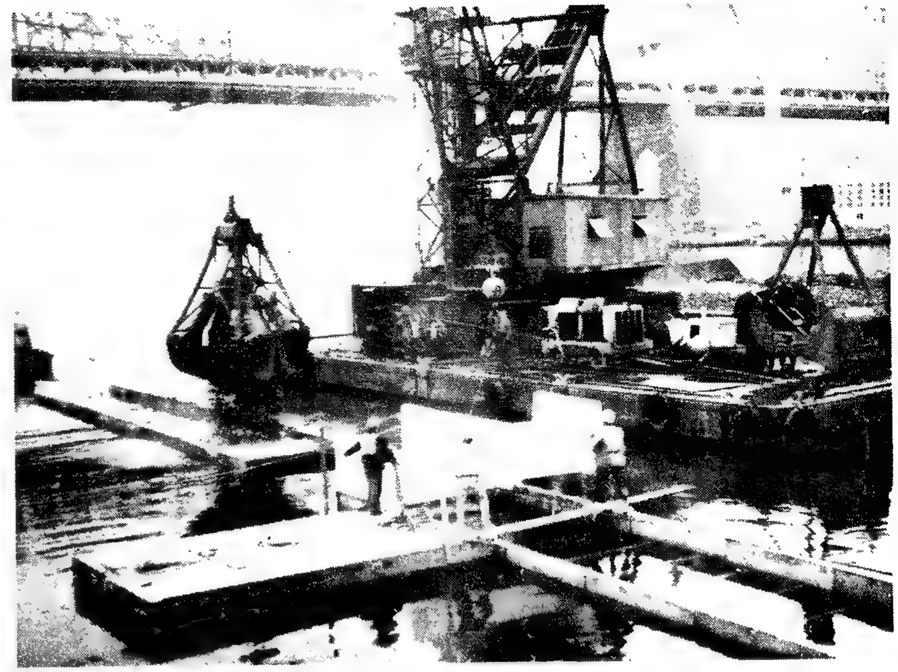
- ENGINEERED
- TESTED
- PROVEN

### ADVANTAGES

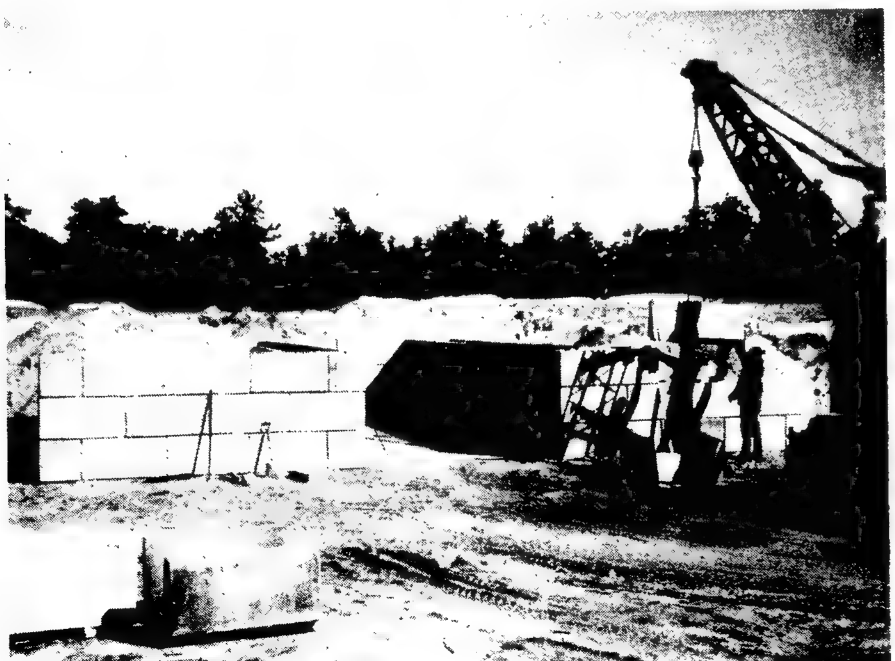
1 Unequalled speed of erection.
2 Rugged one piece interlocking component.
3 Control of hydrostatic pressure.
4 Aesthetic appearance (Precast Finish).
5 Minimum of excavation.
6 Unlimited wall heights.
7 No construction delays.



HIGHWAY AND RAILROAD IMPROVEMENT



SHORE, RIVER AND HARBOR WORKS



POLLUTION CONTROL AND LAND RECLAMATION

## APPLICATIONS

| | |
|---|---|
| Flood control | Bridge abutments |
| Slide corrections | Explosion & Fire Walls |
| Site improvement | Storage bins |
| Loading decks | Bluff stabilization |
| Head walls and ramps | Erosion control |
| Noise & wind barriers | Deep pit structures |
| Military bunkers | Emergency uses |

STA-WAL®

**STRUCTURES OFFER:**

Substantial cost savings
100% salvable
Standard units available from licensed manufacturers

**CONCRETE SYSTEMS INC.**

Gentlemen:

We are pleased to call your attention to Sta-Wal (R), a reinforced concrete interlocking unit for use in the design and construction of GRAVITY retaining wall structures.

The interlocking STA-WAL (R) units rapidly form a wall that is pleasing in appearance and versatile in design concept.

Its flexibility and structural integrity permit its use for general construction projects such as:

1. Highway Retaining Walls
2. Bridge Abutments and Wing Walls
3. Railroad Site Improvements
4. Power Plants
5. Flood and Canal Walls
6. Bank and Bluff Stabilization
7. Hydraulic Intake and Outlet Works
8. Shore, River and Harbor Works
9. Shielding and Explosion Barriers
10. Industrial Storage Bins
11. Refuse Transfer Stations
12. Land Reclamation

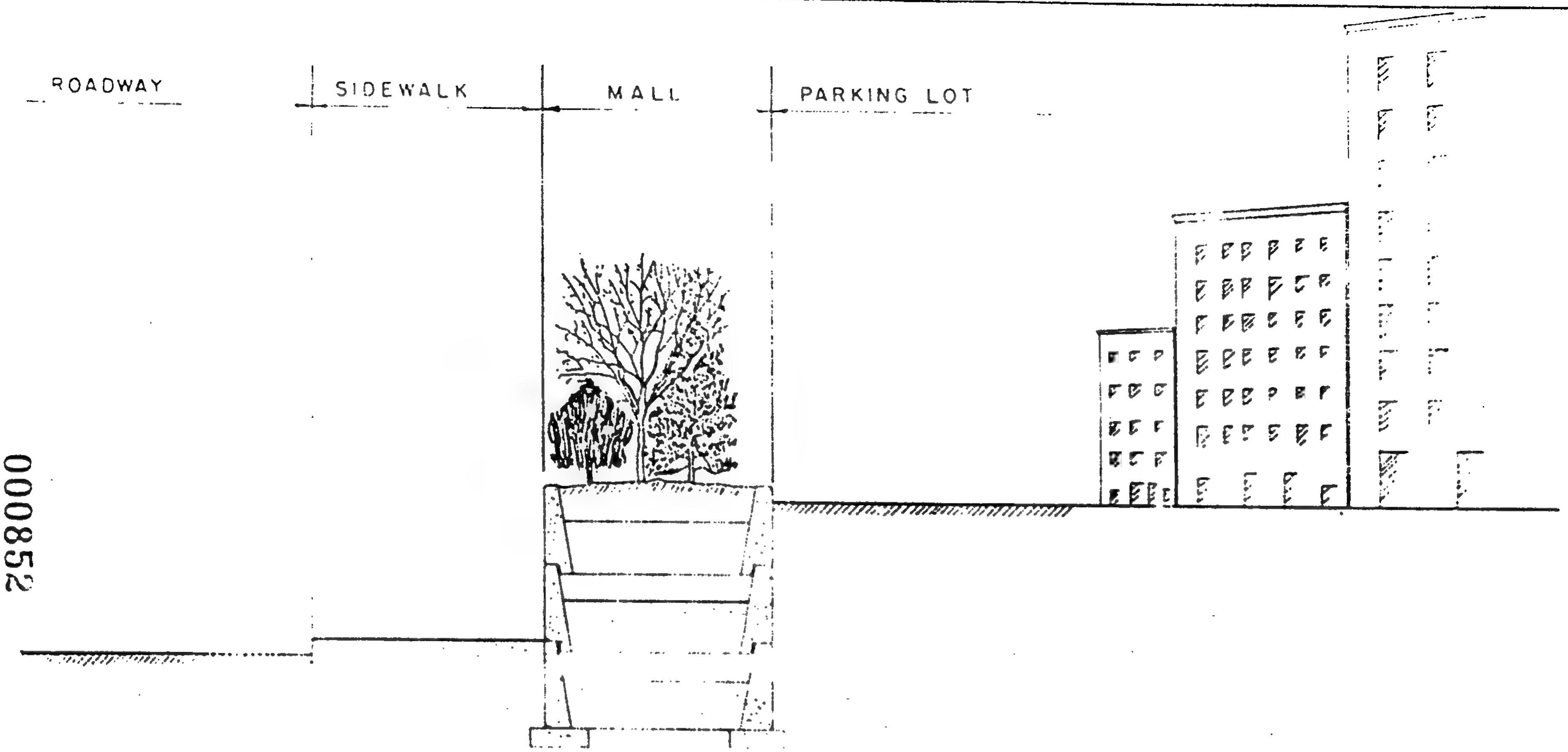
Any engineer or architect considering the use of STA-WAL (R) is invited to send us available data affecting the design and we will suggest a wall to meet the conditions. The essential information is length and height of wall, cross sections if possible; bearing power of soil, kind of fill material, surcharge or superimposed load, any critical clearances; amount of water in the fill; depth of water fronting structure, ect.

We would be glad to meet you at your place of business or in the field to discuss the many benefits and conveniences of our wall system.

Very truly yours,

Leonard A. Worden

COMMERCIAL AVENUE, HUDSON, NEW HAMPSHIRE 03051 603 889 4163



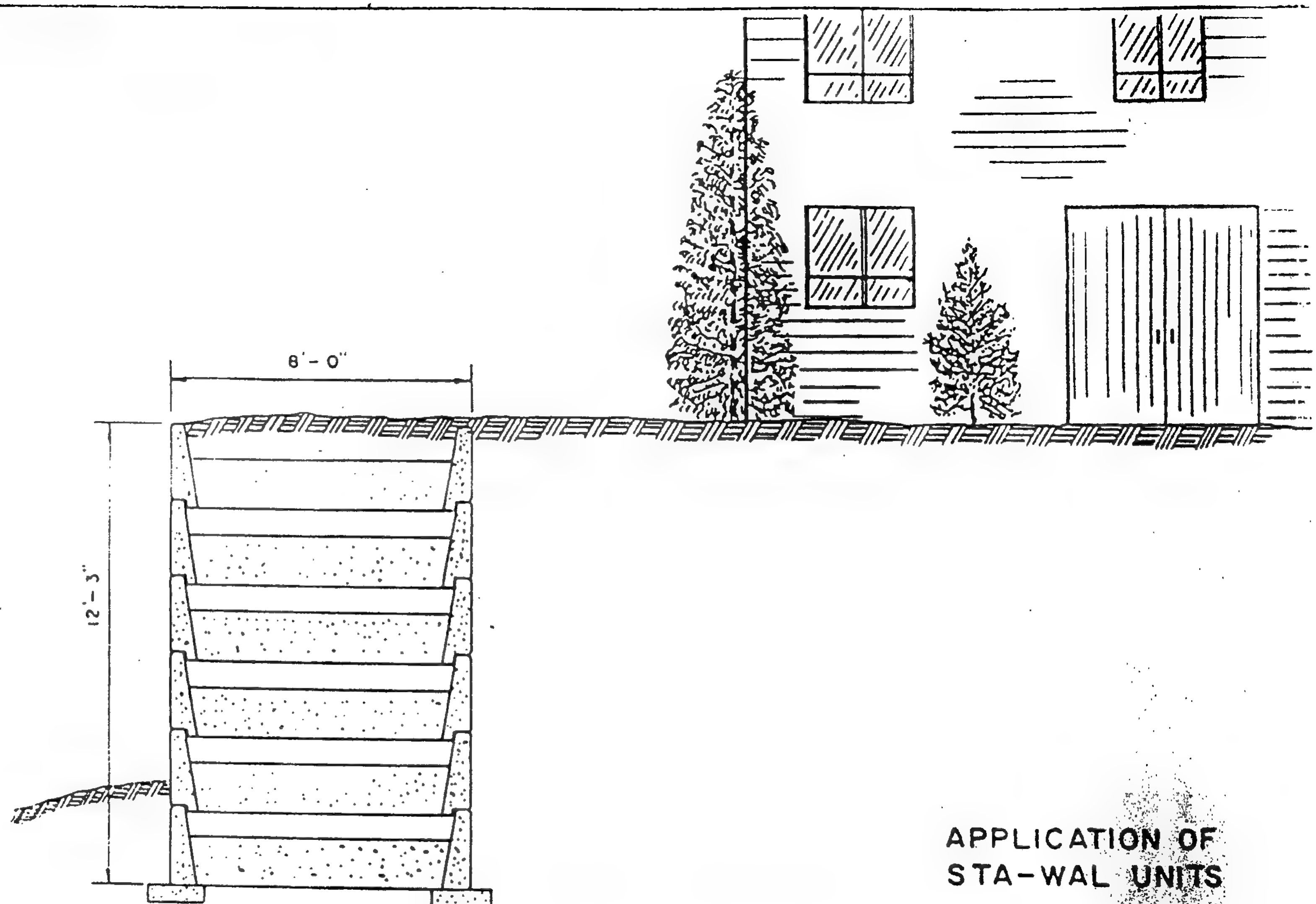

APPLICATION OF
STA-WAL UNITS

SHOPPING CENTER DEVELOPMENT

FFICE COMPLEX

BE IFICATION PROGRAMS

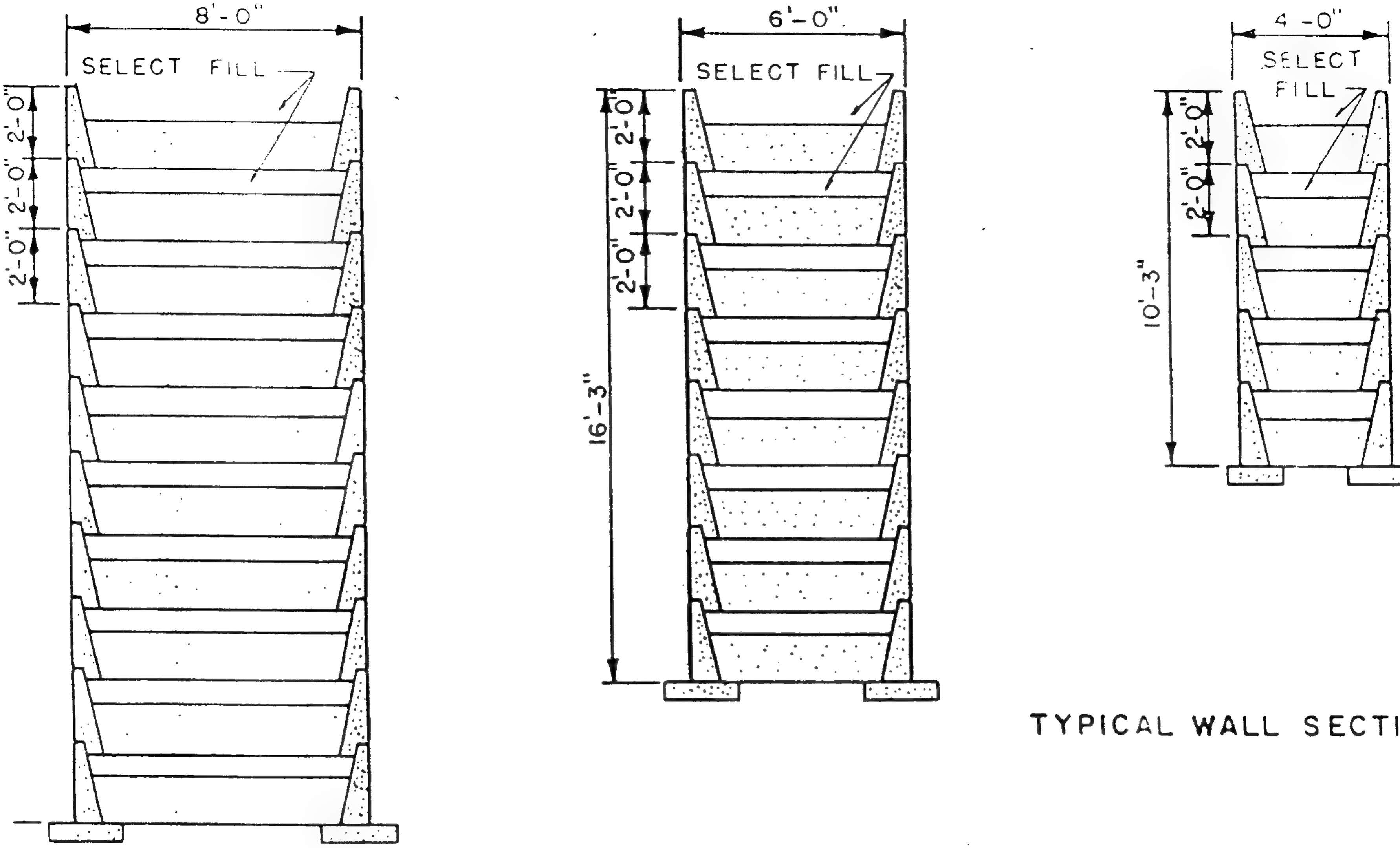
000852




APPLICATION OF
STA-WAL UNITS

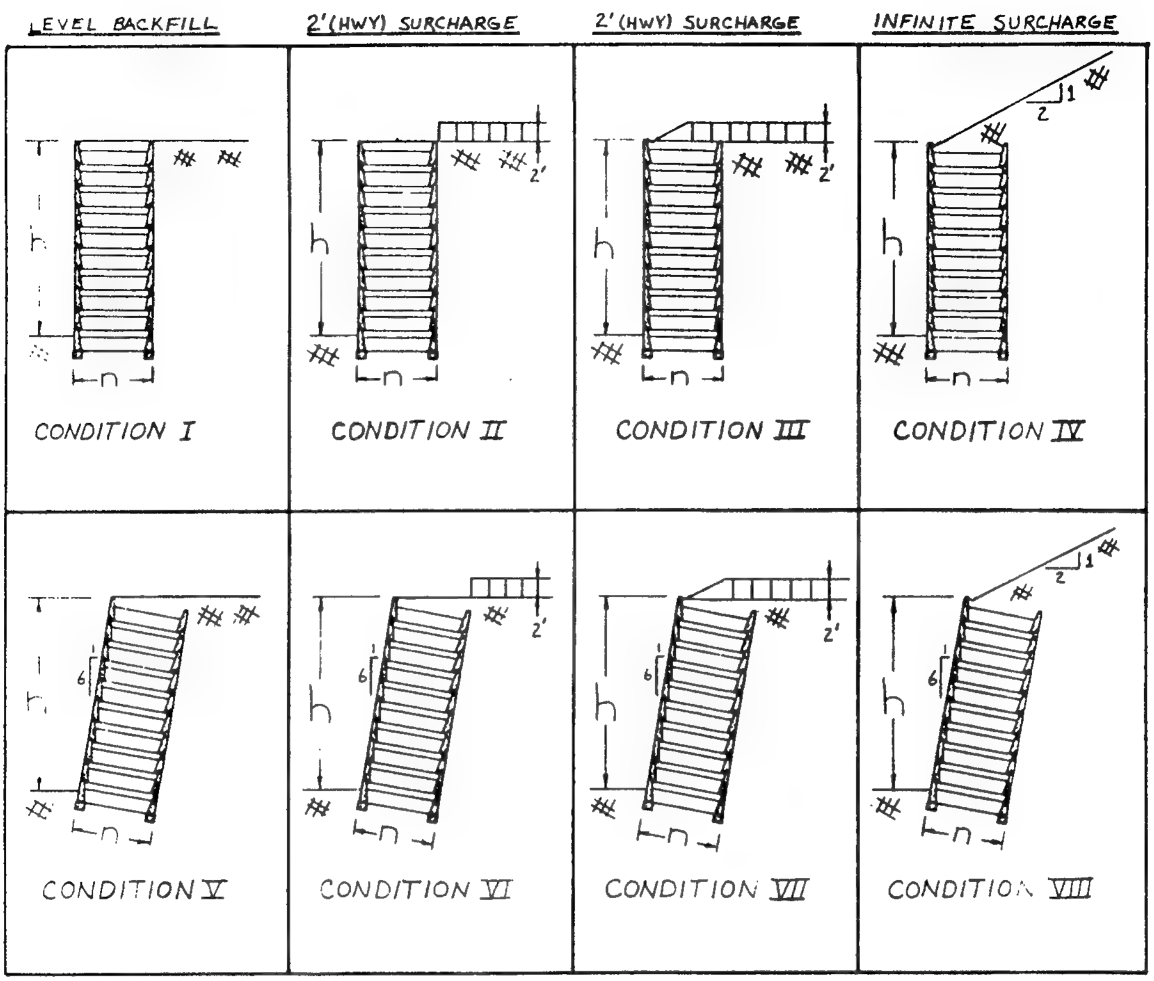
LAND RECLAMATION PROJECTS

SITE DEVELOPMENT



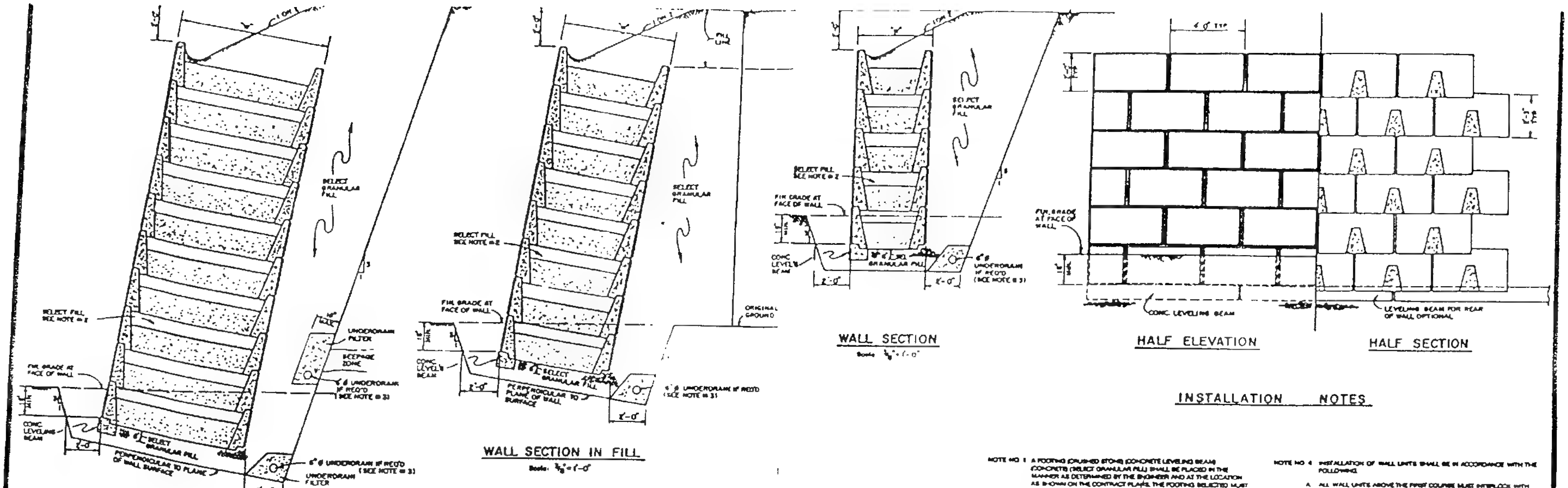

TYPICAL WALL SECTIONS

# STA-WAL® SIZE SELECTION




## VALUES OF "n" (DEPTH OF WALL UNIT)

| COND. \ h | 8' | 10' | 12' | 14' | 16' | 18' | 20' | 22' | 24' | 26' | 28' | 30' | 32' | 34' | 36' | 38' | 40' | 42' | 44' | 46' | 48' | 50' | 52' |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| I | 4 | 4 | 6 | 6 | 6 | 8 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 | 16 | 16 | 18 | 18 | 20 | 20 |
| II | 4 | 6 | 6 | 6 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 16 | 16 | 16 | 18 | 18 | 18 | 20 | 20 | 20 |
| III | 4 | 6 | 6 | 6 | 8 | 8 | 8 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 16 | 16 | 18 | 18 | 18 | 20 | 20 | 20 |
| IV | 6 | 6 | 8 | 10 | 10 | 12 | 12 | 14 | 14 | 16 | 16 | 18 | 18 | 20 | 20 | | | | | | | | |
| V | 4 | 4 | 4 | 4 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 10 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 14 | 16 | 16 |
| VI | 4 | 6 | 6 | 6 | 8 | 8 | 8 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 16 | 16 | 16 | 18 | 18 | 18 | 20 | 20 |
| VII | 4 | 4 | 6 | 6 | 6 | 8 | 8 | 8 | 8 | 10 | 10 | 12 | 12 | 12 | 14 | 14 | 14 | 16 | 16 | 16 | [illegible] | 18 | 18 |
| VIII | 4 | 4 | 6 | 6 | 8 | 8 | 10 | 12 | 12 | 14 | 14 | 16 | 16 | 18 | 18 | 20 | 20 | | | | | | |




WALL SECTION IN CUT

Scale: 1/4" = 1'-0"

WALL SECTION IN FILL

Scale: 1/8" = 1'-0"

WALL SECTION

Scale: 1/8" = 1'-0"

HALF ELEVATION

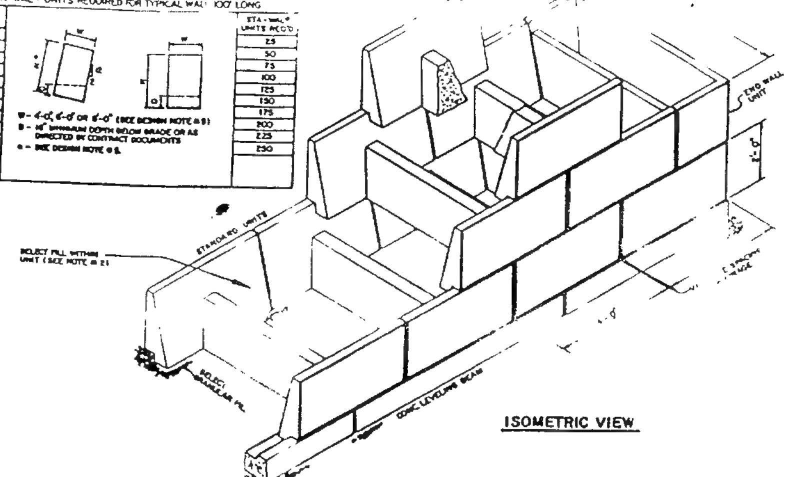
HALF SECTION

# TYPICAL STA-WAL® INSTALLATIONS

STA-WAL® UNITS REQUIRED FOR TYPICAL WALL 100' LONG

| HEIGHT OF WALL 'H' | STA-WAL® UNITS REQ'D |
|---|---|
| 2 | 25 |
| 4 | 50 |
| 6 | 75 |
| 8 | 100 |
| 10 | 125 |
| 12 | 150 |
| 14 | 175 |
| 16 | 200 |
| 18 | 225 |
| 20 | 250 |

W – 4'-0", 6'-0" OR 8'-0" (SEE DESIGN NOTE # 5)
D – 18" MINIMUM DEPTH BELOW GRADE OR AS DIRECTED BY CONTRACT DOCUMENTS
θ – SEE DESIGN NOTE # 5.




ISOMETRIC VIEW

DESIGN NOTES

1. [illegible]
2. WALL FOUNDED IN RIVER OR STREAM BED: CONSIDERATION MUST BE GIVEN TO PREVENT LOSS OF SUPPORTING SOILS BY TRACTIVE FORCES ALONG THE WALL. THE TYPE OF PROTECTION REQUIRED SHALL BE DETERMINED BY FOUNDATION SITE INVESTIGATION AND THE TRACTIVE FORCES DEVELOPED DURING FLOOD STAGE.
3. WALL SUBJECT TO WAVE ATTACK: WHERE WALL IS FOUNDED IN AREAS SUBJECT TO WAVE ATTACK, ERODABLE MATERIAL FRONTING BENEATH AND BEHIND THE WALL MUST BE PROTECTED FROM SCOUR UNDERCUTTING, WASH-OUT AND OVERTOPPING TO ASSURE STABILITY OF THE WALL. THE TYPE OF PROTECTION REQUIRED SHALL BE DETERMINED BY SITE INVESTIGATION AND ANALYSIS OF THE SEVERITY AND FREQUENCY OF WAVE ATTACK. (SPECIFIC SHAPED STA-WAL UNITS MAY BE REQUIRED IN AREAS SUBJECT TO SEVERE WAVE ATTACK).
4. [illegible]
5. DESIGN OF STA-WAL RETAINING WALLS: USE ACCEPTED ENGINEERING PRACTICE FOR GRAVITY WALL DESIGN. REFER TO GRAPH [illegible]
6. [illegible] AVAILABLE FROM THE MANUFACTURER (SPECIFIC SHAPED STA-WAL UNITS ARE AVAILABLE FOR WALL HEIGHTS EXCEEDING [illegible]).
7. CHANGES IN ELEVATION & DIRECTION: STA-WAL UNITS MAY BE STEPPED TO MEET A CHANGE IN GRADE. STA-WALL CAN BE BUILT TO ANY DEGREE OF CURVATURE OR WITH ABRUPT CHANGE OF DIRECTION.

GENERAL NOTE
TECHNICAL SERVICES ARE AVAILABLE FROM THE MANUFACTURER ON DESIGN NO'S 1, 2, 3, 4, 6 AND 7. REFER TO MANUFACTURER FOR USE OF STA-WAL UNITS FOR HARBOR AND COASTAL STRUCTURES.

## INSTALLATION NOTES

NOTE NO. 1 A FOOTING (CRUSHED STONE) (CONCRETE LEVELING BEAM) (CONCRETE) (SELECT GRANULAR FILL) SHALL BE PLACED IN THE MANNER AS DETERMINED BY THE ENGINEER AND AT THE LOCATION AS SHOWN ON THE CONTRACT PLANS. THE FOOTING SELECTED MUST BE PREPARED TO ASSURE A LEVEL FIRST COURSE OF WALL UNITS FOR VERTICAL WALL INSTALLATIONS. THE FOOTING SELECTED FOR BATTERED WALLS MUST BE PREPARED TO ASSURE THAT THE WALL FACE IS PERPENDICULAR TO THE FOOTING.

A. REMOVAL OF UNSUITABLE FOUNDATION MATERIAL MAY BE ORDERED BY THE ENGINEER IF HE DETERMINES IT IS NECESSARY IN ORDER TO PROVIDE A STABLE BEDDING CONDITION FOR THE WALL. IF UNDERCUTTING IS ORDERED BY THE ENGINEER, THE LIFT THICKNESS AND COMPACTION REQUIREMENTS SHALL BE ORDERED BY THE ENGINEER. WHEN WALLS ARE TO BE FOUNDED IN AREAS WHERE UNSUITABLE MATERIAL EXISTS, SPECIAL CONSTRUCTION PROCEDURES AND DETAILS WILL BE SHOWN ON THE PLANS.

B. WHERE CONCRETE SPREAD FOOTINGS ARE SPECIFIED FOR SEATING OF THE WALL UNITS, THE BOTTOM OF THE FOOTING MUST BE PLACED BELOW FROST LINE OR AS DIRECTED BY THE ENGINEER.

NOTE NO. 2 PLACEMENT OF SELECT GRANULAR FILL MATERIAL WITHIN CONCRETE BIN WALLS SHALL BE IN ACCORDANCE WITH THE FOLLOWING:

A. WHERE CONCRETE BIN WALLS ARE TO BE FILLED WITH STONE FILLING AS CALLED FOR IN THE SPECIFICATION, THE MATERIAL SHALL BE PLACED IN A MANNER ACCEPTABLE TO THE ENGINEER TO ACHIEVE MAXIMUM STABILITY. DUMPING OF STONE FILL WITH A FREE FALL GREATER THAN 5 FEET WILL NOT BE PERMITTED.

B. WHERE CONCRETE BIN WALLS ARE TO BE FILLED WITH SELECT GRANULAR FILL AS CALLED FOR IN THE SPECIFICATION, THE MATERIAL SHALL BE PLACED AND COMPACTED IN A MANNER ACCEPTABLE TO THE ENGINEER TO ACHIEVE MAXIMUM STABILITY. DUMPING OF SELECT GRANULAR FILL WITH A FREE FALL GREATER THAN 5 FEET WILL NOT BE PERMITTED.

NOTE NO. 3 A SYSTEM TO DRAIN WATER FROM THE BACK FACE OF THE WALL MAY BE REQUIRED. THE TYPE AND EXTENT OF THE DRAINAGE SYSTEM WILL DEPEND ON THE TYPE OF BACKFILL EXPECTED TO BE USED, THE COMBINED HEIGHT AND BACKFILL, ANTICIPATED SURFACE RUN-OFF AND LOCATION OF THE WATER TABLE IN THE AREA.

NOTE NO. 4 INSTALLATION OF WALL UNITS SHALL BE IN ACCORDANCE WITH THE FOLLOWING:

A. ALL WALL UNITS ABOVE THE FIRST COURSE MUST INTERLOCK WITH THE LOWER COURSE.

B. VERTICAL JOINTS ARE STAGGERED WITH EACH SUCCESSIVE COURSE. THE SELECT FILL PLACED IN THE BINS MAY BE USED TO CONTROL THE VERTICAL JOINT OPENINGS OR AS APPROVED BY THE ENGINEER.

C. UNITS ARE TO BE ERECTED BY THE USE OF A LIFTING EYE WHICH CAN FREELY ROTATE (360°) ABOUT THE VERTICAL AXIS OF THE ANCHOR, PERMITTING BOTH VERTICAL OR DIAGONAL PULLS. A GRAVITY ACTION SAFETY PIN TO PREVENT ACCIDENTAL OPENING [illegible] MUST BE AN INTEGRAL PART OF THE LIFTING EYE.

D. THE ELEVATION OF THE BACKFILL BEHIND THE WALL SHALL NOT EXCEED THE ELEVATION OF THE FILL MATERIAL PLACED IN THE WALL SECTION. THE SELECT FILL IS TO BE PLACED IN THE CONCRETE BIN SECTION EVERY OTHER COURSE OR AS MAY BE DIRECTED BY THE ENGINEER.

E. PLACEMENT OF SELECT FILL IN CONCRETE BIN AREA AND BACKFILL BEHIND WALL SHALL CLOSELY FOLLOW ERECTION OF SUCCESSIVE COURSES OF WALL UNITS OR AS DIRECTED BY THE ENGINEER.

F. SELECT FILL SHALL BE PLACED TO PROVIDE UNIFORM AND ADEQUATE SUPPORT OF THE FIRST AND SUCCESSIVE COURSES OF WALL UNITS AT PROPER LINE, GRADE AND BATTER.

G. ANY DEVIATION FROM LINE AND GRADE, WHICH IN THE OPINION OF THE ENGINEER, IS EITHER DANGEROUS TO THE STABILITY OR DETRACTS FROM THE APPEARANCE OF THE WALL, SHALL BE CORRECTED BY THE CONTRACTOR AT HIS OWN EXPENSE. ALL DAMAGED PORTIONS OF THE WALL, FROM ANY CAUSE WHATSOEVER SHALL BE REPLACED AT THE CONTRACTOR'S EXPENSE AS DIRECTED BY AND IN A MANNER APPROVED BY THE ENGINEER.

[illegible] DWG UPDATED
CONSULT MANUFACTURER
FOR CHANGES

CONCRETE SYSTEMS
RR 3 COMMERCIAL AVE., HUDSON, N.H. 03051

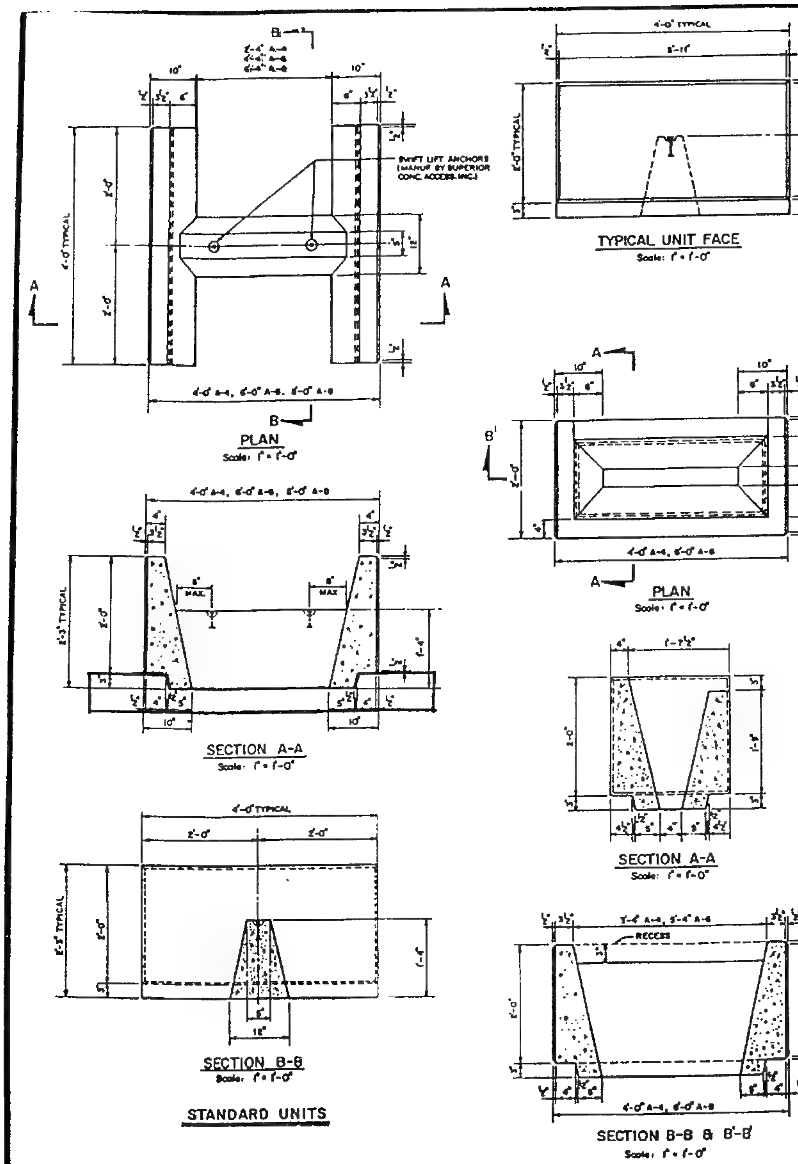
STA-WAL®

TYPICAL INSTALLATIONS

CONCRETE INTERLOCKING STA-WAL®
BIN-TYPE RETAINING WALL

SHEET # 1

000856



PLAN
Scale: 1" = 1'-0"

SECTION A-A
Scale: 1" = 1'-0"

SECTION B-B
Scale: 1" = 1'-0"

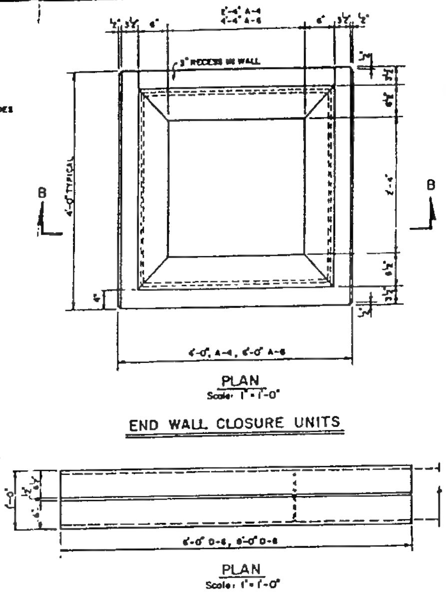
STANDARD UNITS

TYPICAL UNIT FACE
Scale: 1" = 1'-0"

PLAN
Scale: 1" = 1'-0"

SECTION A-A
Scale: 1" = 1'-0"

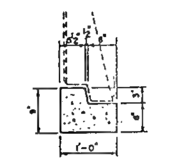
SECTION B-B & B'-B'
Scale: 1" = 1'-0"



PLAN
Scale: 1" = 1'-0"

END WALL CLOSURE UNITS

PLAN
Scale: 1" = 1'-0"



LEVELING BEAM DETAIL
Scale: 1" = 1'-0"

| STA-WAL ® UNITS | | | | |
|---|---|---|---|---|
| TYPE A | STANDARD WALL UNITS | | | |
| A-4 | 4' LONG | 4' WIDE | 2' HIGH | 12.2 C.F. |
| A-6 | 4' " | 6' " | 2' " | 14.1 " |
| A-8 | 4' " | 8' " | 2' " | 18.0 " |
| TYPE B | END WALL UNITS (HALF UNITS) | | | |
| B-4 | 2' LONG | 4' WIDE | 2' HIGH | 6.15 C.F. |
| B-6 | 2' | 6' | 2' | 10.6 |
| TYPE C | END WALL UNITS (FULL UNITS) | | | |
| C-4 | 4' LONG | 4' WIDE | 2' HIGH | 16.3 C.F. |
| C-6 | 4' | 6' | 2' | 21.2 |
| TYPE D | LEVELING BEAM | | | |
| D-6 | 6'-0" LONG | | | 3.6 C.F. |

TOTAL WEIGHT PER L/F OF WALL (IN POUNDS): W/FILL = 100 P.C.F.

| WALL HEIGHT | TYPE A-4 | | TYPE A-6 | | TYPE A-8 | |
|---|---|---|---|---|---|---|
| | 144# Conc. | 150# Conc. | 144# Conc. | 150# Conc. | 144# Conc. | 150# Conc. |
| 2' | 935 | 953 | 1,355 | 1,376 | 1,775 | 1,800 |
| 4' | 1,870 | 1,905 | 2,710 | 2,753 | 3,550 | 3,600 |
| 6' | 2,805 | 2,858 | 4,066 | 4,129 | 5,325 | 5,400 |
| 8' | 3,740 | 3,810 | 5,420 | 5,505 | 7,100 | 7,200 |
| 10' | 4,675 | 4,763 | 6,775 | 6,881 | 8,875 | 9,000 |
| 12' | 5,610 | 5,715 | 8,130 | 8,258 | 10,650 | 10,800 |
| 14' | 6,545 | 6,668 | 9,485 | 9,634 | 12,425 | 12,600 |
| 16' | 7,480 | 7,620 | 10,840 | 11,010 | 14,200 | 14,400 |
| 18' | 8,415 | 8,573 | 12,195 | 12,386 | 15,975 | 16,200 |
| 20' | 9,350 | 9,525 | 13,551 | 13,763 | 17,750 | 18,000 |
| 22' | 10,285 | 10,478 | 14,905 | 15,139 | 19,525 | 19,800 |
| 24' | 11,220 | 11,430 | 16,260 | 16,515 | 21,300 | 21,600 |
| 26' | 12,155 | 12,383 | 17,615 | 17,891 | 23,075 | 23,400 |
| 28' | 13,090 | 13,335 | 18,970 | 19,268 | 24,850 | 25,200 |
| 30' | 14,025 | 14,288 | 20,325 | 20,644 | 26,625 | 27,000 |

SHEET # 2 BEING UPDATED: CONSULT MANUFACTURER FOR CHANGES

## MANUFACTURERS SUGGESTED SPECIFICATIONS

1 STA-WAL. EACH WALL UNIT AS SHOWN ON THE PLAN SHALL BE A MONOLITHIC, REINFORCED CONCRETE STRUCTURE WITH A MINIMUM OF ________ PSI AFTER 28 DAYS. EACH UNIT SHALL CONSIST OF TWO FACE PANELS MEASURING 4 FEET LONG, 2 FEET HIGH. EACH PANEL IS HELD FIXED AND RIGID BY A CONNECTING ARM TO PROVIDE GRAVITY WALL DEPTHS OF 4, 6, AND 8 FEET. (FOR WALL DEPTHS GREATER THAN 8 FEET, CONSULT THE MANUFACTURER)

2 MANUFACTURING OF STA-WAL UNITS. PRODUCTION OF THE WALL UNITS ARE LIMITED TO A SINGLE PIECE METAL MOLD WITH A MINIMUM WALL THICKNESS OF NOT LESS THAN 1/4" PROPERLY RIBBED AND BRACED TO ASSURE ALIGNMENT AND INTERLOCKING OF THE UNITS WHEN INSTALLED. UNITS ARE TO BE MANUFACTURED BY PLACEMENT OF CONCRETE IN THE OPEN SECTION OF THE TRAPEZOIDAL CONNECTING ARM AND STRUCK TRUE AND LEVEL. NOT LESS THAN TWO RECESSED ANCHORS WILL BE PERMITTED ON EACH PARALLEL SURFACE OF THE CONNECTING ARM. THE ANCHOR HEADS TO BE RECESSED APPROXIMATELY 1/2" BELOW THE SURFACE OF THE CONCRETE

3 TOLERANCES. PERMISSIBLE TOLERANCES FOR STA-WAL UNITS ARE LISTED AS FOLLOWS

| | |
|---|---|
| HEIGHT OF FACE PANEL | ±1/4 |
| LENGTH OF FACE PANEL | ±1/4 |
| DEPTH | ±1/4 |
| INTERLOCKING KEY WIDTH | ±1/4" |

INTERLOCKING KEY LENGTHS AND WIDTH MAY BE MODIFIED FOR CURVED WALLS. MINIMUM KEY LENGTH SHALL NOT BE LESS THAN 14 INCHES AND A WIDTH OF NOT LESS THAN 3 INCHES

4 SHOP DRAWINGS. THE MANUFACTURER OF THE WALL UNITS SHALL SUBMIT SHOP DRAWINGS CLEARLY INDICATING THE FOLLOWING

- A FORM DESIGN AND BRACE DETAIL
- B DIMENSIONS OF WALL UNIT
- C POSITION OF REINFORCEMENT
- D METHOD OF CURING
- E LOCATION AND DESCRIPTION OF ANCHOR METHOD FOR LIFTING WALL UNITS.

5. DESIGN CRITERIA. THE MANUFACTURER OF THE WALL UNIT SHALL FURNISH A GRAPH SHOWING THE SAFETY FACTOR OF THE WALL UNITS AGAINST SLIDING AND OVERTURNING WITH NO SURCHARGE. TECHNICAL DATA SHALL ALSO BE SUPPLIED AS TO UNIT WEIGHTS AND TOTAL WEIGHT PER LINEAR FOOT OF WALL SELECTED

6 INSTALLATION DETAILS. THE MANUFACTURER OF THE WALL UNITS SHALL FURNISH STANDARD SHEETS SHOWING TYPICAL WALL INSTALLATIONS AND CONSTRUCTION PROCEDURES

7 SAMPLES. THE PRODUCER OF THE STA-WAL UNITS WILL, IF REQUIRED PROVIDE A MINIMUM OF THREE UNITS STACKED AND INTERLOCKED AT THE POINT OF MANUFACTURING FOR VISIBLE INSPECTION

8 STEEL REINFORCEMENT. REINFORCING BARS SHALL CONFORM TO THE REQUIREMENTS OF ASTM DESIGNATION ________

9 STA-WAL MANUFACTURERS. MANUFACTURERS OF THE WALL UNITS SHALL HAVE A MINIMUM OF 5 YEARS OF EXPERIENCE IN THE CONCRETE PRECAST FIELD AND HAVE TRAINED PERSONNEL FAMILIAR WITH ERECTION OF PRECAST RETAINING WALL SYSTEMS

| UNIT | STA-WAL® UNIT PROPERTIES TYPE A-4 | TYPE A-6 | TYPE A-8 |
|---|---|---|---|
| GROSS AREA<br>GROSS VOLUME | 4 × 2 = 8 s.f.<br>8 × 4 = 32 c.f. | 6 × 2 = 12 s.f.<br>12 × 4 = 48 c.f. | 8 × 2 = 16 s.f.<br>16 × 4 = 64 c.f. |
| WEIGHT 144 lb CONC<br>WEIGHT 150 lb CONC | 12.2 c.f. × 144 = 1780 lb<br>12.2 c.f. × 150 = 1830 lb | 14.1 c.f. × 144 = 2030 lb<br>14.1 c.f. × 150 = 2115 lb | 16.0 c.f. × 144 = 2300 lb<br>16.0 c.f. × 150 = 2400 lb |
| FILL VOLUME<br>FILL % BY VOLUME | 32 - 12.2 = 19.8 c.f.<br>19.8/32 = 61.9% | 48 - 14.1 = 33.9 c.f.<br>33.9/48 = 70.6% | 64 - 16 = 48 c.f.<br>48.0/64 = 75% |
| FILL WGT @ 100 p.c.f.<br>CONC % BY VOLUME | 19.8 × 100 = 1980 lb<br>100 - 61.9 = 38.1% | 33.9 × 100 = 3390 lb<br>100 - 70.6 = 29.4% | 48 × 100 = 4800 lb<br>100 - 75.0 = 25% |
| TOTAL WGT INCL FILL | | | |
| CONC @ 144 lb<br>CONC @ 150 lb | 1780 + 1980 = 3760 lb<br>1830 + 1980 = 3810 lb | 2030 + 3390 = 5420 lb<br>2115 + 3390 = 5505 lb | 2300 + 4800 = 7100 lb<br>2400 + 4800 = 7200 lb |

CONCRETE SYSTEMS
RR 3 COMMERCIAL AVE., HUDSON, N.H. 03051

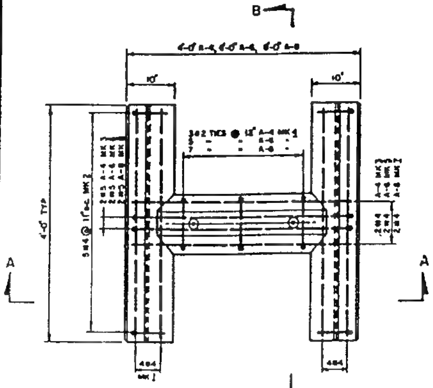
# STA-WAL®

UNIT DETAILS

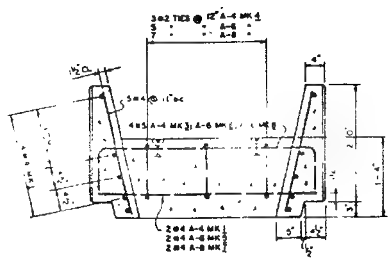
CONCRETE INTERLOCKING STA-WAL® BIN-TYPE RETAINING WALL

SHEET # 2

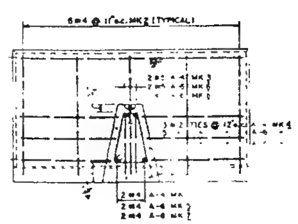
000858



PLAN
(TYPE A)
Scale 1" = 1'-0"

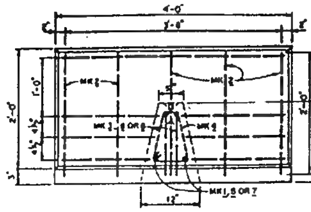


SECTION A-A
Scale 1" = 1'-0"

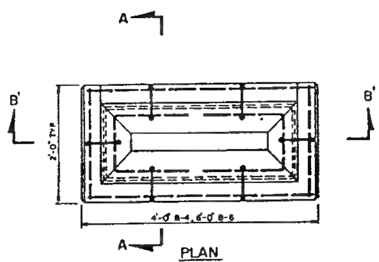


SECTION B-B
Scale 1" = 1'-0"

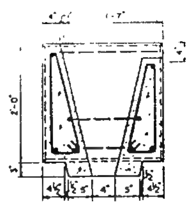
STANDARD UNITS



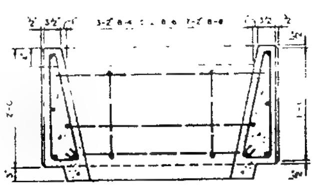
TYPICAL REINFORCING PATTERN
Scale 1" = 1'-0"



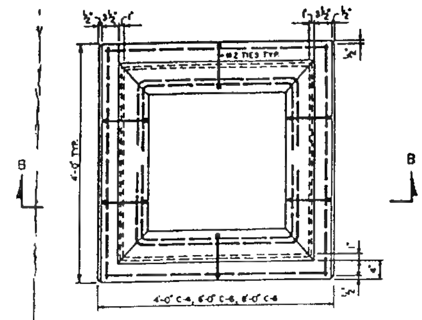
PLAN
(TYPE B)
Scale 1" = 1'-0"



SECTION A-A
Scale 1" = 1'-0"

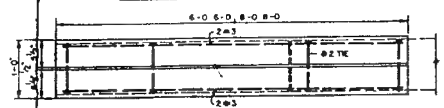


SECTION B-B & B'-B'
Scale 1" = 1'-0"

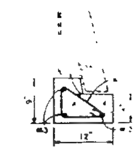


PLAN
(TYPE C)
Scale 1" = 1'-0"

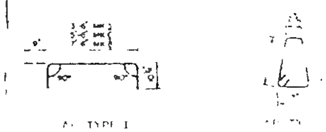
END WALL CLOSURE UNITS



PLAN
(TYPE D)
Scale 1" = 1'-0"



LEVELING BEAM DETAIL
Scale 1" = 1'-0"



BAR DETAIL
Not to Scale

NOTE: TYPICAL REINFORCEMENT PATTERN SHOWN FOR TYPES B, C & D. SEE MANUFACTURER'S DESIGN FOR BAR SIZES & LOCATIONS

REINFORCING SCHEDULE

| UNIT TYPE | MARK NO. | BAR TYPE | NO. REQ'D | BAR SIZE | LENGTH | WEIGHT LBS. | |
|---|---|---|---|---|---|---|---|
| A-4 | 1 | STR | 10 | #4 | 3'-8" | 24.5 | |
| | 2 | STR | 10 | #4 | 2'-0" | 13.4 | |
| | 3 | I | 2 | #5 | 8'-0" | 10.4 | |
| | 4 | II | 3 | #2 | 3'-7" | 1.6 | |
| | | | | | | 49.9 | |
| | | | | | | | |
| A-6 | 1 | STR | 8 | #4 | 3'-8" | 19.6 | |
| | 2 | STR | 10 | #4 | 2'-0" | 13.4 | |
| | 4 | II | 5 | #2 | 3'-2" | 2.7 | |
| | 5 | STR | 2 | #4 | 5'-8" | 7.6 | |
| | 6 | I | 2 | #5 | 7'-0" | 14.6 | |
| | | | | | | 57.9 | |
| | | | | | | | |
| A-8 | 1 | STR | 8 | #4 | 3'-8" | 19.6 | |
| | 2 | STR | 10 | #4 | 2'-0" | 13.4 | |
| | 4 | II | 7 | #2 | 3'-2" | 3.8 | |
| | 7 | STR | 2 | #4 | 7'-6" | 10.2 | |
| | 8 | I | 2 | #5 | 9'-0" | 18.7 | |
| | | | | | | 65.5 | |
| | | | | | | | |
| B-4 | 1 | STR | 4 | #3 | 3'-6" | 5.5 | |
| | 2 | STR | 4 | #3 | 1'-8" | 2.5 | |
| | 3 | TIE | 6 | #2 | 4'-6" | 4.6 | |
| | 4 | I | 2 | #4 | 3'-8" | 4.9 | |
| | | | | | | 17.5 | |
| | | | | | | | |
| B-6 | 1 | STR | 4 | #4 | 1'-8" | 4.6 | |
| | 2 | STR | 6 | #4 | 5'-8" | 22.7 | |
| | 3 | TIE | 6 | #2 | 4'-6" | 4.6 | |
| | 4 | I | 4 | #5 | 5'-8" | 23.6 | |
| | | | | | | 55.4 | |
| | | | | | | | |
| C-4 | 1 | STR | 8 | #3 | 3'-8" | 11.1 | |
| | 2 | TIE | 6 | #2 | 4'-6" | 4.6 | |
| | 3 | I | 2 | #4 | 6'-0" | 8.0 | |
| | | | | | | 23.7 | |
| | | | | | | | |
| C-6 | 1 | STR | 4 | #4 | 3'-6" | 7.1 | |
| | 2 | STR | 6 | #4 | 5'-8" | 22.7 | |
| | 3 | I | 8 | #2 | 4'-6" | 5.2 | |
| | 4 | I | 2 | #5 | 7'-8" | 16.0 | |
| | 5 | I | 2 | #5 | 7'-10" | 16.3 | |
| | | | | | | 68.3 | |
| | | | | | | | |
| D-6 | 1 | STR | 3 | #3 | 5'-6" | 6.4 | |
| | 2 | TIE | 3 | #2 | 2'-6" | 1.3 | |
| | | | | | | 7.7 | |
| | | | | | | | |
| D-8 | 1 | STR | 3 | #3 | 7'-6" | 8.7 | |
| | 2 | TIE | 4 | #2 | 2'-6" | 1.7 | |
| | | | | | | 10.4 | |
| | | | | | | | |

NOTE: ALL REINFORCING TO BE DEFORMED BARS (EXCEPT #2 TIES) $f_y$ 60,000 PSI STEEL, AS REQUIRED. [illegible] SPECIFIED IN ASTM DESIGNATION A 305

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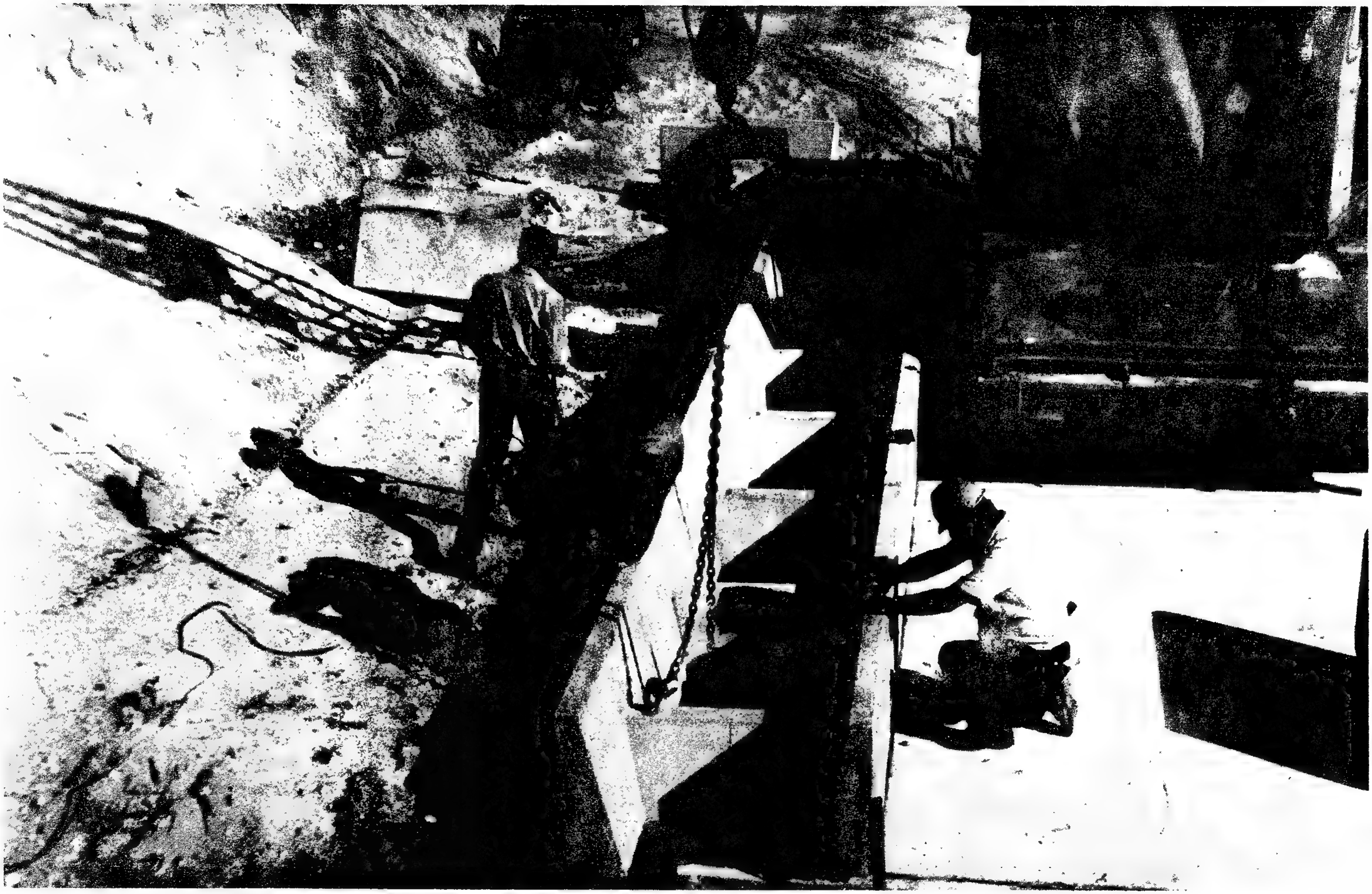

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# CRITERIA FOR THE SELECTION OF BLAST ATTENUATION DEVICES

by

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## ABSTRACT

To prevent the entry of destructive blast effects into protected facilities, air intakes and exhausts, and other openings, must be provided with blast resistant closures or blast attenuation devices. A variety of blast valves and other closure devices are available in the market place. Guidance on the selection of appropriate devices is presented. Selection criteria take into account the design threat, blast fragility levels of equipment, human tolerance to blast, air flow and functional requirements, architectural considerations, and cost factors.

The characteristics of pass-thru blast waves behind blast activated values are examined to assess the importance of peak pass-through pressure, valve closing time and pass-thru blast impulse. A few formulas are presented for making preliminary estimates of internal blast conditions, based on pass-thru wave characteristics. The influence of blast duration on the vulnerability of personnel and equipment is discussed, and a generic failure curve along with a preliminary list of blast fragility levels is presented for the classes of equipment likely to be found in blast protected facilities. Recommendations are made to assist designers in selecting appropriate blast attenuation solutions.

Paper prepared for presentation at Defense Research Institute conference "Securing Installations Against Car-Bomb Attack", May 15-17 1986, Arlington, Virginia.

## CRITERIA FOR THE SELECTION OF BLAST ATTENUATION DEVICES

### Introduction

In most blast protected facilities air requirements for personnel and equipment are provided by means of openings to the outside. In general these openings can be closed for only brief intervals when the facility is fully occupied and fully operational. To be prepared for a local detonation, means must be provided to prevent the entry of destructive blast effects through these openings. A variety of blast valves and other closure devices are available in the market place, representing a wide range of sophistication and costs. Design guidance on the selection of appropriate blast attenuation devices for intake and exhaust openings is discussed in this paper. In choosing a solution, consideration should be given to the threat being protected against; the fragility of personnel and equipment to blast effects penetrating the facility; functional requirements of the installation; architectural considerations; and the economy of the solution. Guidance is provided to aid designers in making a rational selection.

### The Blast Environment Outside

In the usual case of the detonation of a high energy explosive device, the violent release of energy creates a sudden pressure disturbance (blast wave), which is characterized by an almost instantaneous rise from the ambient atmospheric pressure to a peak pressure termed the Peak Side-On Overpressure ($P_{so}$). This shock front travels away from the burst point with a velocity higher than the speed of sound. The shock front expands radially with a corresponding decrease in the peak overpressure. At a distance from the burst the time history of the blast overpressure is of the form shown in Figure 1. The peak overpressure decays exponentially to the ambient (atmospheric) value in the

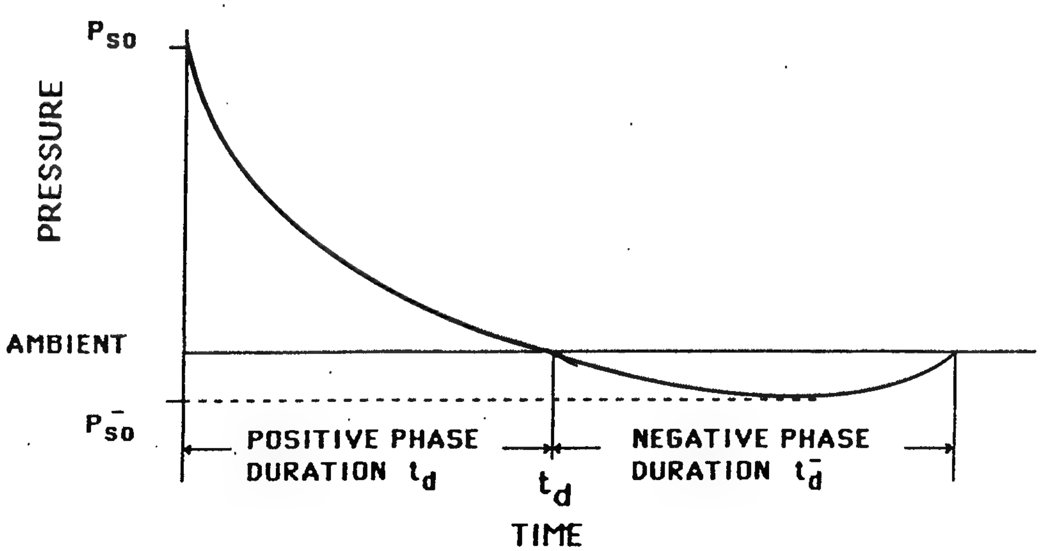



**Figure 1. Free Field Blast Pressure-Time Variation**

time ($t_d$), which is the positive phase duration. This is followed by a period of time during which the pressure is below the original ambient pressure, referred to as the negative phase or the suction phase, with a corresponding peak underpressure ($P_{so}^-$) and negative phase duration ($t_d^-$). The local pressure then returns to the ambient conditions which existed before the explosion.

The blast threat to a facility is defined in terms of the energy released by the explosion (usually in terms of an equivalent weight of TNT), and a specified distance and orientation relative to the burst point. Blast parameters needed for the evaluation and design of blast resistant components are available in many standard sources, such as Reference 1 for conventional explosives and Reference 2 for nuclear weapons. If the shock wave impinges on a rigid or nearly rigid surface, a reflected pressure ($P_r$) is instantaneously developed on the surface, raising the pressure on the surface to a value greater than the incident pressure. The peak value of the reflected pressure depends on the strength of the incident blast wave and the angle formed between the reflecting surface and the plane of the shock front. The duration of the reflected pressure is controlled by the dimensions of the reflecting surface.

To characterize the blast environment outside of an air intake or exhaust opening the orientation of the opening with respect to the burst point and the geometry of the area in the vicinity of the opening must be considered. If the opening is oriented side-on to the blast wave (i.e. positioned with its axis perpendicular to the direction of blast propagation), the absence of a reflecting surface will limit the pressure outside of the opening to the side-on over pressure. On the other hand, if the opening is facing the burst point, and presents a sizeable reflecting area, the opening will be subjected to reflected pressure which may be several times greater than the side-on pressure.

The above discussion of blast wave characteristics is general and equally applicable to conventional (high energy) explosives and nuclear weapons. In the former case, distances are measured in terms of feet, while in the latter, distances are measured in miles.

**The Blast Environment Inside**

In the absence of closures or blast attenuation devices, potentially destructive blast effects may have free access to the inside of the protected space. The resulting environment in intake and exhaust pipes and ducts, and interior spaces of the facility may be characterized by two effects: a rapid rise in internal pressure ($P_i$) and secondary internal blast waves emanating from the openings. Blast attenuation devices are intended to limit these effects. The effectiveness of any blast attenuation system can be measured in terms of how much damage would result if the system were not provided, and how this damage would affect operation of the facility.

Internal pressure build-up and secondary internal blast waves are affected by the geometry of openings and the characteristics of blast attenuation devices.

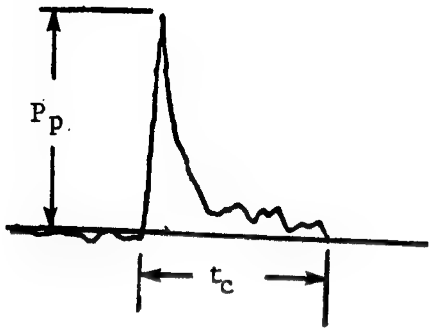
A discussion of blast closure systems and attenuation devices, along with a review of potential blast damage to personnel and equipment is presented next, to provide the background for making rational choices of blast protection systems.

**Blast Closure Systems and Blast Attenuation Devices**

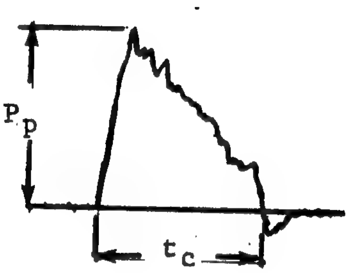
A variety of techniques present themselves for the solution of the problem, namely either completely shutting out the blast, or, reducing blast effects to levels which can be tolerated by equipment and personnel being protected. Some of the more commonly applied techniques are described below along with a brief discussion of their applicability and major advantages and disadvantages. Many of these techniques can be applied either singly or in combination.

**Manual Closures:** Hatches, covers, or manually operated valves, butterfly valves, etc. can be used to manually close all openings in anticipation of a detonation. Closures would be required to remain in the closed position as long as there is a threat. All equipment requiring air for operation must remain shut down during the closed-up period. In occupied facilities, carbon dioxide build-up, oxygen depletion and elevated temperatues may control the permissible closed-up period unless special life support equipment is provided. Manual closures may have merit in nuclear blast hardened facilities where ample warning time may be available to manually close all openings, particularly since in the post-nuclear blast environment, fires may contaminate the outside air, requiring the facility to remain closed up for a period of time.

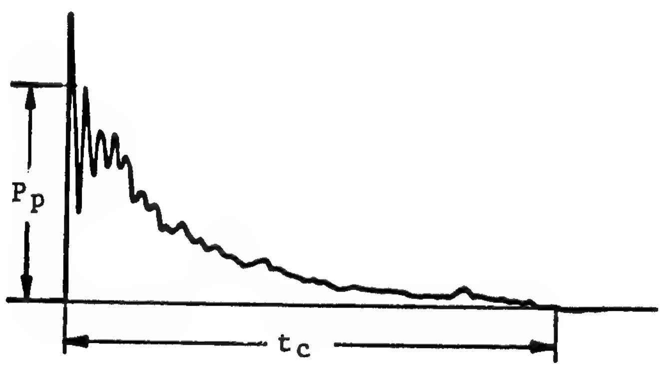
**Blast Activated Valves:** Most modern blast activated valves consist of closing plates which are pressed against a housing by the passage of the blast wave, thereby cutting off the flow. The closing plate is typically round and held in position by springs which return it to the open position after the passage of the blast wave. One manufacturer uses flexible spring steel rectangular strips as a closing plate. Although there are blast valves which are designed to remain closed until they are manually tripped open, most valves are designed to close inward against the positive phase of the blast wave, and then to close outward against the negative (suction) phase of the blast, and to finally return to the fully open position when the blast wave has passed. Blast activated valves modify the blast effects which would otherwise penetrate the facility through the opening. Since the blast wave itself provides the force to close the valve, a portion of the blast wave passes through the valve while it is closing. How much of the blast wave gets through depends upon the configuration of the valve, the magnitude of the pressure acting on the valve and the valve closing time. The remainder of the incident blast wave is denied entry into the protected space by the action of the closed valve. The shock front and part of the shock wave are separated from the flow, consequently the portion passing through the valve no longer represents a fully developed flow but only an immediate pressure pulse. Typical pressure-time histories behind the valves of three suppliers (American, European and Scandinavian) are shown in Figure 2. The pressure-time histories of the pass-thru waves are characterized by a peak pass-thru pressure ($P_p$) and a closing time ($t_c$). The




(a) An American Supplier




(b) A European Supplier




(c) A Scandanavian Supplier

**Figure 2. Typical Pressure-time Histories of Pass-thru Waves Behind Blast Activated Valves**

area under the pressure-time curve during the closing time is the impulse (I) of the pass-thru wave. In Figure 2(a) the pass-thru pressure drops rapidly in an almost triangular fashion during the initial stages of the closing of the valve. During the remainder of the closing, pass-thru pressures are much lower than the initial peak value, and very little impulse is associated with this phase of the closing. The pressure-time history in Figure 2(b) is quite different, as high pressures are sustained throughout the closing of the valve. The curve in Figure 2(c) almost resembles an exponential decay. Potentially damaging internal pressures and secondary shock waves in spaces behind a blast valve will depend upon the characteristics of the pass-thru wave. This is developed in more detail in a subsequent section, as a means of providing guidance on judicious choosing among a variety of available devices.

Major advantages of blast activated valves in protecting blast resistant facilities are that they cause only a momentary interruption of the air supply i.e. a few milliseconds. If it is desirable to have control over the re-opening of intakes and exhausts (such as in a post-nuclear attack, or if war gasses and/or lethal biological agents are present in the atmosphere) a blast activated valve which remains closed until manually tripped open can be used. A theoretical disadvantage of blast activated valves in general is that a portion of the shock wave gets past the valve. This may or may not be a problem depending on the strength and duration of the pass-thru wave, the down-stream configuration, and the fragility levels of items to be protected.

**Sensor Activated Blast Closure Systems:** Sensor activation is achieved by a device which senses some attribute of the detonation and transmits a signal back to a built-in control system which automatically closes the valve. These devices are more common in nuclear blast resistant facilities where the thermal flash, the prompt nuclear radiation, the electromagnetic pulse (EMP), ground shock, or the blast wave itself may be activating media. Sensor activation is rarely practical in facilities designed to resist conventional explosions, since pressure type sensors would have to be placed some distance away from the opening to enable signal transmittal and valve closing before arrival of the blast wave. Due to the potential closeness of the burst to the opening, and the speed of the shock wave, pressure activated sensors may not be able to close the valve before blast effects have already penetrated the facility.

**Tunnel Attenuation of Blast Waves:** Historically, tunnel systems have been used to mitigate blast effects penetrating a facility. The propagation of an initially peaked short duration blast wave in a tunnel is characterized by an attenuation of the peak pressure; however, this is accompanied by an increase in the duration of the blast wave, the consequence being little attenuation in the blast energy. A tunnel attenuates blast energy primarily by wall surface friction conversion into thermal energy. Long tunnel lengths are therefore generally required to produce required reductions in blast energy. Tunnels are seldom a practical and economical means of attenuating blast effects, unless the tunnel is needed for some other purpose (i.e. an alternate escape route, etc.). When this is the case, blast valves are frequently still needed at the end of the tunnel. Due to the long duration of the blast wave in nuclear

hardened facilities, extremely long tunnels would be needed to affect a substantial reduction in the peak pressures transmitted by a tunnel.

**Blast Effects on Personnel and Equipment**

Rational selection of blast attenuation devices for air intake and exhaust openings should be based on considerations of potential blast effects on personnel and equipment being protected. A brief overview of the subject is presented here. Addressed are the types of equipment which may be expected to be found in a blast protected facility. A detailed treatment of the subject is beyond the scope and intent of this paper; however, a more complete compendium of available data should be undertaken to aid designers of future blast protected facilities. Damaging effects are characterized by blast induced overpressures within the protected facility and diffraction loading developed as moving blast waves interact with objects. The time-history of the blast induced loading generally has an influence on the damaging potential of the blast, but little data are available to fully characterize these effects. Some limited data on the influence of blast duration on human injury and the failure of filters are included herein.

**Personnel Injuries:** Human injury from blast may be characterized as three types: Primary, due to the overpressure of the blast wave alone; secondary, from impact by debris from damaged equipment and structure; and tertiary, by striking a stationary object after acceleration by the blast forces (Reference 3). Damage to the lungs is associated with primary blast injury of a serious nature. Figure 3, which is based on data contained in Reference 4, shows

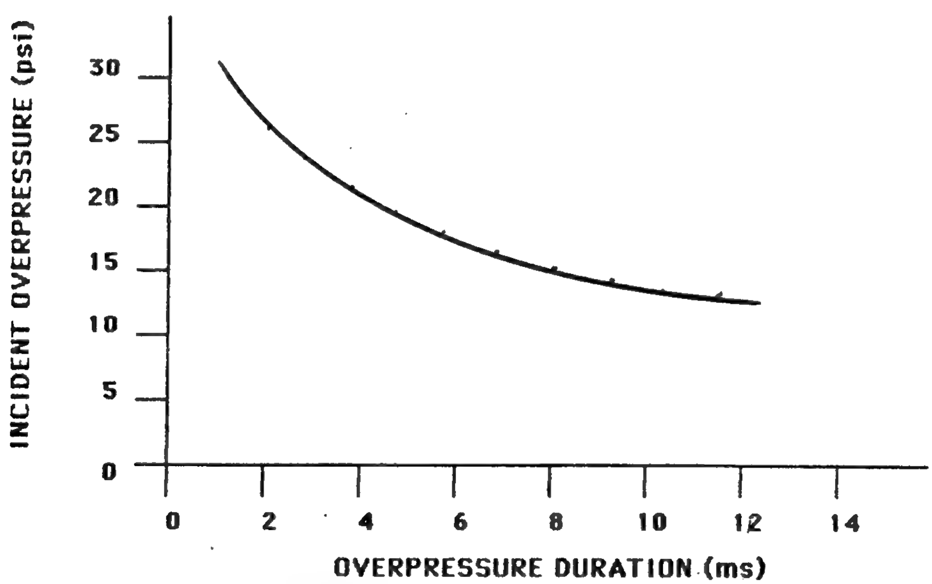



**Figure 3. Dependence of Human Lung Injury on Incident Blast Overpressure and Duration**

the dependence of the threshold of lung injury on peak overpressure and duration of the blast wave. With a duration of 10 milliseconds, the threshold overpressure for lung damage is approximately 15 psi, but for a 2 millisecond pressure pulse, the threshold damage level is almost 25 psi (66 percent higher). Eardrum damage is the lowest level primary effect of blast on personnel. Its dependence on blast wave duration for very short duration pressure pulses is not well documented. Reference 3 indicates a threshold level of about 3.0 psi for long duration pulses.

Equipment Blast Damage: The primary types of equipment which may be expected to be found in blast protected facilities may be grouped as follows:

Air Handling Equipment

- Filters
- Fans
- Blowers
- Ducts, pipes, and flexible connections
- Plenum chambers
- Dampers
- Etc.

Mechanical/Electrical Equipment

- Engine-generator sets
- Control devices
- Combustion air intakes, exhausts, silencers and mufflers
- Fuel tanks and fuel lines
- Heaters, compressors/condensers (air conditioning)
- Etc.

Electronic and Communications Equipment

- Computers and peripherals
- Radio transmitters and receivers
- Display consoles
- Etc.

In general this equipment may be expected to be located in a variety of positions throughout the facility; however, certain equipment, by its nature, may always be expected to be located near an air intake or exhaust, or even in a duct or plenum chamber. Filters, for example, are in this category. Also, among the types of equipment listed above, perhaps with the exception of certain electronic equipment, filters may be the most susceptible to blast damage. Because of this, and because they are one of only a few items for which detailed test data are available,filters are singled out for a more detailed examination of blast damage.

Various types of filters are commonly installed in the air intakes of blast resistant facilities including: blast resistant pre-filters, ordinary panel

high-efficiency particulate air (HEPA) filters of the type used in the ventilation systems of nuclear power facilities, and chemical biological (CB) filters commonly required where chemical and/or biological warfare agents may be a threat. Long duration blast pressures of about 2 psi will cave in ordinary panel type filters and severely reduce their efficiency (References 5 and 6). Reference 7 gives the structural limits of standard and high capacity HEPA filters subjected to simulated blast loading for several American, British and European models. Results are given in Tables 1 and 2. In reference 7 the effect of blast wave duration on the failure overpressure of HEPA filters was

**Table 1.** Structural Limits of Standard HEPA Filters Subjected To Simulated Explosion Transients 47 ms Long (From Reference 7)

| Manufacturer | Structural Limits | |
|---|---|---|
| | kPa | psi |
| A | 17.2 | 2.50 |
| B | 17.4 | 2.53 |
| C | 7.2 | 1.04 |
| D | 9.5 | 1.86 |
| Average | 12.8 | 1.86 |

**Table 2.** Structural Limits Of High-Capacity HEPA Filters Subjected to Simulated Explosion Transients 47 ms Long (From Reference 7)

| Manufacturer | Structural Limits | |
|---|---|---|
| | kPa | psi |
| E | 5.5 | 0.8 |
| F | 5.5 | 0.8 |
| G | 9.7 | 1.4 |
| H | 6.9 | 1.0 |
| Average | 6.9 | 1.0 |

investigated. The results show that a filter (Manufacture E) which failed at 0.8 psi when subjected to a 47 millisecond blast wave, was able to survive up to 1.45 psi in a 5 millisecond blast wave duration (about an 80% increase). This shows the strong dependence of failure pressure on the duration of the blast pulse.

Other classes of equipment would be expected to show dependencies of failure overpressure on blast pulse duration similar to HEPA filters and human lungs. Duration dependent blast failure levels are not generally available. However long duration blast failure levels for equipment may be available, and if an

estimate can be made of the natural period (T) of the failed component, the form of the duration dependent failure curve can be approximated by means of the generic failure curve shown in Figure 4. This curve assumes an initially peaked triangular pressure-time variation with a peak pressure $P_m$ and a duration $t_d$. Furthermore it assumes that the equipment response can be characterized by a linearly elastic single degree-of-freedom system, and that failure is associated with the onset of inelastic deformations. Similar curves can be constructed for other pressure-time profiles (exponential, rectangular, etc.) other failure criteria, and other systems. The ordinate of Figure 4 is the dimensionless ratio of the peak pressure $P_m$ (which an item can survive at a specific duration $t_d$) to the "long duration" blast failure pressure $P_{ld}$. For purposes of this discussion "long duration" is taken to mean a duration at least ten times longer than the natural period of the failed element. Knowing the properties of the blast wave $P_m$ and $t_d$, and the long duration blast failure pressure $P_{ld}$ and natural period T of the failed element, Figure 4 can be entered to determine if the item is safe (points which fall below the failure curve) or if it fails (points which fall above the curve). This curve must be used cautiously since it assumes that the mode of failure is the same for low pressures with long durations as it is for higher pressures with short durations. This is not always the case. For example a flexural member may fail in bending at low pressures, and in shear at higher pressures with shorter durations. This would necessitate a cut-off on the left-hand side of Figure 4 as the failure mode transitions from bending to shear. Regarding the natural period, it should be recognized that any given piece of equipment has many resonant periods. Consider for example an axial fan. The fundamental period for the blades will in general be different from that for the housing, the shaft, the mounting structure, etc. So the natural period which is referred to above is the one associated with the actual element which failed at the specified long duration failure pressure.

The failure curve in Figure 4 can be characterized by three regions. Beginning on the left, in the region for which $t_d/T$ is less than about 0.1, the peak response (and hence the failure) will occur well after the pressure pulse is over. Consequently the actual values of $P_m$ and $t_d$ and the shape of the pulse are insignificant (neglecting cut-offs). Failure is governed almost entirely by the impulse of the blast wave (i.e. the area under the pressure-time curve. Equipment failures in this "impulse region" may be said to be impulse sensitive. In the region to the right of $t_d/T$ of about 5 the failure curve is essentially flat. Failure in this region occurs very early during the loading and the duration of the loading becomes insignificant. Equipment failures in this "pressure region" may be said to be pressure sensitive. In between these two regions (i.e. in the range of $t_d/T$ of 0.1 to 5.0) the actual characteristics of the pressure-time pulse (i.e. $P_m$ and $t_d$) can have an influence on equipment failure. This is the "pressure-time" region of an equipment failure curve. These three regions are indicated in Figure 4.

Listed in Table 3 are preliminary estimates of the probable ranges of long duration failure overpressures for the classes of equipment of interest. Of course, for a specific item the manufacturer may be able to provide detailed

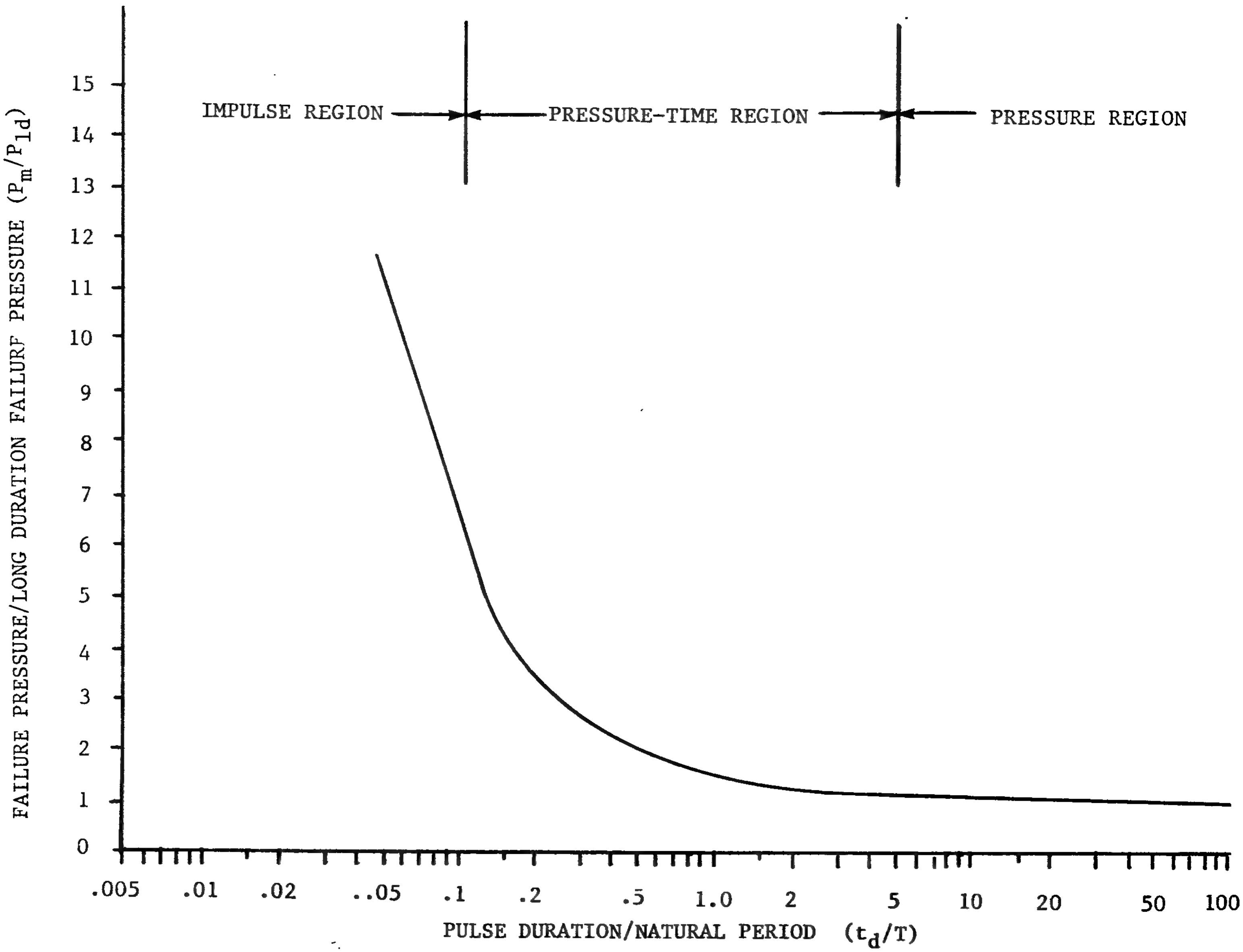



Figure 4. Generic Equipment Failure Curve for Triangular Loading



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Table 3. Equipment Blast Fragility Levels

| Description | Estimated Range of Long Duration Blast Failure Pressures (psi) |
|---|---|
| High Capacity HEPA Filters | 0.5 - 1.5 |
| Standard HEPA Filters | 1 - 3 |
| Panel Filters | 1.5 - 3 |
| Prefilters (Blast Hardened) | 5 - 20 |
| CBR Filters (Internal Pressure) | 5 - 15 |
| CBR Filters (External Pressure) | 2 - 6 |
| Sheet Metal Ducts (Internal Pressure) | 3 - 6 |
| Sheet Metal Ducts (External Pressure) | 1.5 - 3 |
| Fans and Blowers (Internal Pressure) | 5 - 25 |
| Fans and Blowers (External Pressure) | 3 - 20 |
| Engine Generator Sets | 5 - 20 |
| Engine Air Intakes | 5 - 15 |
| Engine Exhausts | 10 - 30 |
| Heaters | 5 - 15 |
| Fuel Tanks (External Pressure) | 5 - 25 |
| Fuel Lines (External Pressure) | 5 - 50 |
| Air Conditioning Compressors/Condensers | 2.5 - 10 |
| Computers and Peripherals | 1 - 5 |
| Radio Transmitters and Receivers | 1 - 5 |
| Display Consoles (CRT's etc) | 1 - 3 |

information on the blast vulnerability, but this is seldom the case. In addition, certain items may be specially designed as blast hardened in accordance with a military specification. Such items may, therefore, have blast failure overpressures greater than values shown in Table 3. This table is very preliminary; what is needed is a more complete compendium of blast fragility levels for the classes of equipment expected to be located in blast protected facilities. In addition, a compilation of estimates of the natural periods of the item listed in Table 3 should be developed. Such data would aid designers in making judgements concerning equipment survival in cases where detailed data are not readily available.

### Selecting Blast Attenuation Devices

Blast attenuation solutions should be based on considerations of the characteristics of blast effects which penetrate protected spaces, and the ability of personnel and equipment to withstand these effects. In the absence of any form of closures or blast attenuation devices the blast environment induced in intake and exhaust pipes, ducts, plenums and interior spaces of a blast protected facility may be characterized by a rapid rise in internal pressure ($P_i$), and secondary internal blast waves caused by the hostile blast environment outside. These internal blast effects will depend on the geometry of the openings, the physical layout of the facility, and outside blast environment. Blast attenuation devices which are not fully closed at the time of blast wave arrival will allow a portion of the blast wave to pass into the facility. Examples include sensor activated devices which do not close fast enough, and blast activated valves in which the blast wave itself provides the force to close the valve. Typical pass-thru waves for blast activated valves are shown in Figure 2. These waves are characterized by a peak pass-thru pressure ($P_p$), a duration ($t_c$) usually assumed to be the same as the closing time, and a pass-thru impulse (I) previously defined. All valves will not produce identical interior pressures and secondary shock waves, so a means is needed to evaluate internal conditions based on specific valve characteristics. To accomplish this simplified approximate relationships are presented for evaluating peak internal pressures and secondary blast waves based on pass-thru wave characteristics and the geometry behind the valve. These same relationships can be used to determine whether or not blast attenuation devices are needed in specific applications. In this case the pass-thru wave may be the actual pressure-time curve for the outside environment (as in Figure 1) unattenuated as it enters the protected space through an openning. More sophisticated solutions and computer codes exist for these calculations, but the intent here is to provide designers with simple tools with which to assess the need for blast attenuation devices, and to make judicious choices.

### Peak Internal Pressure ($P_i$)

In the absence of blast attenuation devices the internal pressure rise due to a blast wave entering through an unprotected opening may be a potential hazard. Since this is a mass flow phenomenon, the hazard becomes more pronounced as the duration of the blast wave increases. In a nuclear blast environment the

hazard may be very real. In the blast environment of conventional explosions the hazard may become pronounced if unprotected openings are large in area and/or the volume of the protected space is small. Even with blast activated valves, internal pressure can become a problem in ducts, plenums, and expansion chambers, and in small spaces, depending on the fragility levels of the equipment being protected and the characteristics of the pass-thru wave. In addition internal pressures may have the potential to damage intake and exhaust pipes and distribution ducts. By cutting off the flow, well designed blast valves can usually prevent the build up of damaging internal pressures. An approximate differential equation for the internal pressure build-up, based on experimental data reported in Reference 8 (concerning a shock wave entering a chamber through an entrance area which is small compared to the volume of the chamber immediately behind the entrance) and formulas derived in Reference 9, is given by:

$$dP_i(t)/dt = 5(P_p(t) - P_i(t))^{.5736}\ (A/V) \qquad (1)$$

in which

| | |
|---|---|
| $P_i(t)$ | is the time history of the internal pressure build-up (psi) |
| $P_p(t)$ | is the time history of the pass-thru pressure wave entering the chamber (psi) |
| A | is the area of the opening ($ft^2$) |
| V | is the volume of the chamber ($ft^3$) |
| t | is the time in milliseconds (ms) |

This expression, which lends itself to numerical solution, may be used to estimate the pressure-time history in the space immediately behind openings with or without blast attenuation devices, if the pass-thru pressures ($P_p$)is 150 psi or less, and the pressure-time history of the pass-thru wave is known. The area (A) is to be taken as the actual area immediately behind the opening (or the valve) where the pass-thru pressure-time is characterized, and if more than one valve or opening exists, A may be taken as the sum of the areas. For the case of blast activated valves, typical profiles of the pass-thru wave are given in Figure 2, and are characterized by a peak pass-thru pressure $P_p$, a closing time $t_c$, and a pass-thru impulse I. The following approximate formula may be used to make a preliminary estimate of the peak internal pressure ($P_i$), as long as ($P_i$) is less than 10 percent of ($P_p$).

$$P_i = Kt_c(A/V)(P_p)^{0.5736} \qquad (2)$$

in which (K) is a factor which accounts for the shape of the pass-thru wave.

For a rectangular pass-thru wave K = 5
For a triangular pass-thru wave K = 3.15

This expression clearly shows the influence of the peak pass-thru pressure ($P_p$), closing time ($t_c$) and pass-thru wave shape on the internal pressure

build-up in a protected space. Although the above expressions are expected to give quite good predictions of internal pressure for simple entrance geometries and relatively small openings, locations near entrances may be affected more by secondary blast waves which propagate into the facility.

**Peak Internal Blast Wave Pressure ($P_s$)**

Pass-thru blast waves which exist at openings (with or without blast attenuation devices) may subsequently propagate into the protected space. These blast waves expand geometrically into the interior, decaying in amplitude and reflecting off internal surfaces. The penetration of short duration air blast into protective structures was studied in Reference 10. Empirical relationships developed in Reference 10 may be modified to give a first approximation of secondary shock waves in spaces behind blast valves. The peak side-on pressure ($P_s$) in spaces immediately behind a blast valve may be expressed in terms of the peak pass-thru pressure ($P_p$), the geometry of the opening and distance from the opening as follows:

$$P_s = C(P_p)(A)^{.675}/(R)^{1.35} \tag{3}$$

in which

- $P_s$ is the peak side-on pressure at a location behind the blast valve (psi)
- $P_p$ is the pass-thru pressure (psi)
- $A$ is the area of the opening ($ft_2$)
- $R$ is the distance from the center of the opening to the location of interest (ft)
- $C$ is a coefficient which depends on the angle (a) between the normal to the center of the opening and the location of interest and is given by $C = 0.65\ (1 - 0.25a)$

In the case of several closely spaced openings or blast valves, the area A may be taken to be the sum of the areas. Although this expression is at best approximate, it can be used to make preliminary estimates of internal shock pressures which may exist at various locations of interest (such as critical equipment locations, etc.) based on blast valve characteristics. As such, it may also be used to assess the influence of the geometry behind the valve and valve performance. The actual behavior of interior blast waves is fairly complex as shock waves may experience multiple reflections from interior surfaces. Equation (3) represents only side-on blast pressures, before reflections occur. Combined pressure pulses resulting from multiple reflections may be evaluated using more sophisticated techniques as discussed in Reference 10.

**Internal Blast Environment as a Criterion for Evaluating Blast Attenuation Devices**

The blast environment which a blast attenuation device allows to penetrate a blast protected facility should be a major factor in choosing among various devices. This should be assessed in conjunction with the blast fragility

levels of protected equipment (and personnel). As earlier discussed, even fairly low internal pressures could cause human eardrum rupture and damage to filters and other fragile equipment, such as sheet metal ducts, electronic equipment, etc. Secondary internal shock waves have been shown to be a threat to even more rugged equipment which may be located close to a blast valve opening. Equipment which at times may be expected to be mounted directly in the intake or exhaust, such as fans, blowers, engine intakes (including breathers, filters, etc.), engine exhausts (mufflers, manifolds, etc.), pre-filters, CBR filters, dampers, supply ducts and pipes, flexible connectors, etc. may experience even more directly the effects of the pass-thru wave. At an opening or just behind a blast attenuation device, the blast conditions may be characterized by the pressure-time profile of the pass-thru wave. Peak pass-thru pressure ($P_p$), duration (or closing time) ($t_c$) and pass-thru impulse (I) are the parameters used to describe pass-thru waves. As the pass-thru wave moves downstream these parameters may fluctuate due to geometric changes in the channel size and shape, bends and turns, in-line equipment such as filters, dampers, fans, etc. and other causes of attenuation (or amplificaiton).

A considerable body of analytical and experimental work has been done over the years on characterizing the behavior of blast wave propagation in tunnels, ducting systems and chambers. Some of the results are in the form of computer codes, while other results are applicable to special geometrics and blast conditions. What designers need, in order to make expedient estimates of conditions downstream from openings and blast attenuation devices, are simple expressions, for internal pressure build-up and secondary shock wave pressures. Such computational techniques, combined with equipment blast fragility data will permit designers to make rational decisions in evaluating the need for blast protection of openings, and will provide the basis for making a judicious choice of blast attenuation devices. Equations (1), (2) and (3) and the discussion of blast effects on personnel and equipment presented here just begin to scratch the surface of what is needed.

Of the three basic parameters of the pass-thru wave, ($P_p$), ($t_c$) and (I) no single one can be used as a criterion for value selection. To use pass-thru pressure alone as a selection criterion neglects the effect of blast wave duration on equipment failure levels. Figure 4 shows that this would be valid only for $t_d/T$ values greater than about 5.0. Closing times for blast activated valves are expected to be in the range of 1 to 20 ms. (milliseconds) so to qualify as "pressure sensitive" equipment natural frequencies (the reciprocal of natural periods) would have to be in the range of 250 to 5,000 cps (cycles per second). These frequencies are much higher than what might be expected for the failing elements of the classes of equipment of interest (especially near the 5,000 cps end of the range). Instead, natural frequencies of about 50 cps might be more appropriate. For very rapidly closing valves, with closing times on the order of 2 milliseconds td/T would be less than 0.1 or for equipment with natural frequencies of 50 cps or less. This is in the "impulse region" identified in Figure 4. In this region, since the failure occurs after the pressure pulse is over, the values of the peak pass-thru pressure and closing time become insignificant, and failure is almost completely governed by the

pass-thru impulse of the valve. Closing time however, must be rapid enough to qualify the loading as impulsive. To use closing time alone as a selection criteria for valves would not be valid since it says nothing about the strength of the pass-thru wave. In the region of Figure 4 between values of $t_d/T$ of 0.1 and 5.0 equipment failures may be affected by the combination of the peak pass-thru pressure, the closing time, and the form of the pass-thru wave. For efficient rapidly closing blast valves, the equipment failure region which is expected to be of most interest is the impulse region. In this region pass-thru impulse becomes the governing criteria for the selection of blast attenuation devices.

**Additional Considerations**

The focus thus far has been on the ability of blast attenuation devices to reduce the internal blast environment to levels which can be tolerated by protected equipment and personnel. Other important considerations which should be examined in selecting blast attenuation devices are discussed below.

**Strength Considerations:** Blast attenuation devices are generally rated in terms of the peak incident pressure and/or peak reflected pressure which they can withstand without damage or malfunction. Frequently, to indicate the dependence of valve blast resistance on incident blast wave duration, multiple failure pressure ratings may be given for different durations of the blast wave. This may take the form of one or more pressure rating for "short duration" blast loading and other (lower) ratings for "long duration" blast waves. In fact the failure curve for a blast valve might be expected to be of the same form as Figure 4. A device should never be used when the anticipated outside pressures exceed the rating of the device. If the selected device is rated at a higher pressure than the design threat, an additional margin of safety against more severe threats is achieved. All other factors being the same (including cost), it is always advisable to select the device with the highest pressure rating.

**Fragment Protection:** If potentially damaging fragments from exploding devices are expected to reach exposed blast attenuation devices they will need some form of fragment protection. In blast activated valves, the (moving) valve plate must be lightweight in order to move fast enough, and therefore may not be heavy enough to withstand fragments. Note that blast attenuators located inside of tunnels, expansion chambers and plenums may shed this requirement, but this should not be the major factor in choosing such an approach. Potential disadvantages of tunnels, plenums and expansion chambers are discussed under architectural considerations. If fragment protection is needed, simple, steel or concrete fragment shields can be installed to protect blast attenuation devices.

**Flow Rate and Head Loss:** Criteria for the selection of blast attenuation devices for air intakes and exhausts are based on flow rates that can be attained at head losses within the range of 0.5 to 2.0 inches of water; higher values would excessively increase the power required to drive blowers and fans.

On the other hand, head losses lower than 0.5 inches of water are not necessarily desirable, at least for blast resistant facilities that must be pressurized to prevent the random infiltration of outside air that may be contaminated. Overpressures (velocity heads) of 0.5 and 1.0 inches of water are associated, respectively, with incident wind velocities of about 32 and 45 miles per hour (Reference 11). Manufacturers generally provide data on the rated air flow capacity (cubic feet per minute, CFM) at various head losses (inches of water). Based on the required design flow rate and rated flow capacities, suitable blast attenuation devices can be selected. In all but the smallest facilities more than one device is generally required to accomodate the flow. History has shown that several small attenuation devices, such as blast activated valves, are generally more suitable and more economical than one large device. Most manufacturers of blast activated valves can provide valves either as a single valve, or in modules of two or more valves. One manufacturer can provide a single blast resistant frame containing up to 50 blast valves. The entire assembly is simply cast into the concrete wall. Another manufacturer provides a site assembled structural frame which can accomodate any numer of valves which are installed after the concrete has set.

**Functional Requirements:** Other functional considerations in selecting blast attenuation devices include: whether the device must provide protection against the negative phase of the blast (underpressure), whether it must be gas tight (for example, if smoke and dust, or chemical and biological contaminants may be present outside of the opening), and whether the device is required to re-open automatically or remain closed after the passage of the blast wave. Blast attenuation devices on engine exhausts may be subjected to high temperatures, and could require special heat resistant materials. Blast activated valves meeting all of these requirements are generally available.

**Architectural Considerations:** As previously discussed, whether blast attenuation devices are positioned on vertical surfaces (walls) or horizontal surfaces (roofs) may affect the blast loadings which are experienced (i.e. reflected pressure or side-on overpressure). The use of tunnels and expansion chambers in front of blast attenuation devices for purposes of reducing the loading on the device, is usually not the best solution. A superior approach would be to use a device which can withstand the blast evironment without the need for tunnels and/or expansion chambers. Aside from the savings in costs and space requirements associated with tunnels and expansion chambers, the decrease in the target size may reduce the vulnerability of a facility. The need for a plenum or expansion chamber after a blast attenuation device, to compensate for the inability of the device to attenuate blast levels sufficiently, may also be eliminated by choosing a superior device. Finally, the area required to accommodate blast attenuation devices can be reduced by choosing devices which minimize the area required per unit of air flow, i.e. the number of square feet required per CFM (cubic feet per minute) of air.

**Cost Considerations:** With regard to initial cost, various factors should be considered. Prices of blast valves, for example, vary widely. If considerations of blast threat, pass-thru blast waves and resulting internal pressures

and shocks, and equipment fragility levels are applied, as recommended herein, the requirements imposed on the valve will be well defined. The least costly valve capable of fulfilling the requirements can then be selected. The ease of installation of blast attenuation devices can drastically affect cost. Devices requiring fewer steps in the construction process can result in lower overall construction cost. The trend toward pre-fabricating multiple blast valve modules in blast resistant frames which can be cast directly in the concrete helps keep construction and design costs down. Finally, life cycle costing should be performed to see if what appears to be an inexpensive device could turn out to be more costly in the long run. For example reducing the number of values to keep the area (A) down in equations (2) and (3) may result in higher head losses and a commensurate increase in power consumption, a big factor in life cycle costing.

**Conclusion:**

The selection of blast attenuation devices for ventilation, and equipment intake and exhaust openings in blast protected facilities must be a compromise among sometime conflicting requirements for ample air flow, moderate head loss, adequate strength, rapid closure, adequate attenuation of blast effects, high reliability, ease of installation, and low cost. Ideally, duration dependent blast vulnerability data for personnel and equipment would be used to assess performance in conjunction with estimates of the interior blast environment at specific equipment locations. As discussed, equipment blast vulnerability data is scanty and generally unavailable and design aids for making expedient calculations of internal blast conditons remain to be developed. A few simplified formulas for characterizing internal pressures and secondary blast waves, and limited blast fragility data have been presented along with a technique for inferring time dependent equipment blast failure levels from long duration levels (and natural periods). Consideration of these suggests that for relatively rapidly closing valves the single most important characteristic from the view point of protecting people and equipment, is the value of the impulse of the pass-thru blast pulse. Peak pass-thru pressure becomes a consideration for equipment with very high frequencies but due to inherent stiffness, and strength, failure levels are generally higher than other low frequency equipment which must also be protected. Hence peak pass-thru pressure takes on less importance. Closing time is important in that it is one of the parameters that limits the impulse which can get past an attenuation device, but closing time alone can not be used as a selection criterion. A wide variety of blast attenuation solutions are available, and many manufacturers produce competing devices. Designers are urged to review considerations presented here in selecting appropriate blast attenuation solutions.

## List of References


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# THE EXP DOORS

**The tested and proven anti-explosives door system.**

Presentation on 16 May 1986
to
DRI Seminar

by

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James A. Johnson

## ABSTRACT

The EXP range of doors consists of a system that has been extensively tested against blast effects and fragments as well as against placed and hollow explosive charges.

Doors have been designed to resist placed charges varying from 4lbs to 100lbs and to resist hollow charge devices such as the RPG7.

The closing boltwork is shock-proof and, when required, is designed to remain operational after an attack.

The EXP doors are easy to operate and their construction is simple. They are most cost-competitive.

## 1. INTRODUCTION

The EXP doors are designed to withstand the following attack criteria:

a) a placed charge of military type High Explosives (HE) that is detonated on the front face of the door aiming at breaching the door with a man-hole size opening or at dislocating the closing mechanism enabling the opening of the door after the attack.

A typical criterion is 40lbs of TNT in a cubical shape placed against the door.

b) the delivery on the door of a hollow or shaped charge with the intention of perforating the door panel and to damage targets located behind the door.

A shape charge is a quantity of explosive with geometry formed in such a way that, on detonation, all the explosive energy is concentrated towards a focal point and generates a jet with extraordinary penetration capabilities.

A typical weapon in this category is the RPG7.

## 2. STANDARD DOOR PANEL DESIGN

2.1 The standard design of door panels to resist placed charges is a sandwich section consisting of a front and a rear steel plate, interconnected by a framework of steel beams, with concrete in-fill. Sometimes the concrete is replaced by specialized in-fill materials that are designed to resist specific mechanical or thermal types of attacks.

2.2 The standard design of door panels to resist the penetration of shaped charges is a cross-section similar to the one described above for placed charges but with increased thicknesses of the steel plates and with relatively large stand-off distances between the front and the rear plates. This leads to unusually thick door panels.

When this over-sized thickness becomes a problem, more effective barriers than concrete are introduced such as ceramic materials that are refractory to the hollow charge jet and allow thinner door designs. The disadvantages of these ceramic barriers are that they are expensive and they introduce a hard and brittle element which poorly resists the effects of a placed charge and which directly transfer the full intensity of the shock waves onto the rear plate.

3. THE EXP DOORS

3.1 The EXP door design provides a door panel suited to resist equally well a placed or a shaped charge.

The basic principles of the door panel are:

a) to provide a nominal steel front plate that merely supplies stand-off to the rear plate;

b) to provide a rear plate to resist the blast effects that have travelled to it; and

c) when resistance to hollow charges is also required, to fill the air gap between the front and the rear plate with an effective barrier against the penetrating jet.

The ingenuity of the EXP door design lies in the geometry of the rear plate which is shaped into a relatively flexible membrane that is essentially subjected to direct tensile stresses when under load and to the filling of the door panel with common, inexpensive materials that resist the hollow charge jets.

3.2 When designing against placed charges, the function of the front plate is solely to receive the charge and to provide stand-off to the rear plate. This front plate can thus be constructed of relatively thin plates compatible with the over-all structural serviceability of the panel.

The rear plate is of basic curved shape, either in one direction forming a cylinder, or in two directions forming a hemisphere.

The rear plate is simply welded to the front plate with no intermediate connectors in the form of internal beams.

When the charge placed on the front plate is detonated it easily breaches the front plate and the blast expands itself within the air gap between the front and the rear plate. As the blast impinges the rear cylindrical (or spherical) shell with a radial pressure, the plate wedges itself into the door frame and direct tensile stresses are generated in the plate with little secondary bending and shear.

The elimination of major shear stresses precludes the danger of early breaching or punching which, as shown by tests, is the typical mode of failure of standard door panels.

If the door panel is designed to resist exclusively placed charges, then a hard wood barrier is introduced within the air gap of the door panel. The function of this barrier is to absorb the burning effects of the charge at close proximity. Teak wood is recommended for this purpose and it is usually available in the form of old railway sleepers.

In addition, this additional wood barrier reflects to a certain degree the blast waves and helps to spread the blast pressure effects in a uniform distribution.

Since the rear plate under radial pressure is mainly subjected to direct tensile forces, full use is made of the material elongation capabilities and thin sections are comparatively adequate in the design leading to highly cost-competitive solutions.

3.3 When resistance to hollow charges is required, the door panel is still essentially designed as a placed charge panel but the air gap is replaced by an elementary but effective mixture such as:

- hard granite stones and iron droppings mixed according to a given volume ratio;

- hard granite stones and glass droppings mixed according to a given volume ratio; or

- hard granite stones, iron and glass droppings in given proportions.

The above in-fill mixtures contain a certain volume of air voids which are in fact beneficial to the resistance against hollow jets. Each individual solid component of the mixture offers a good resistance to the hollow charge jet but, in addition, a diffraction phenomenon is observed at each interface of a solid medium with air. The energy of the jet is dispersed every time it crosses an air void between two solid media.

The same door panel with the in-fill materials resists equally well a placed charge because the in-fill mixture does not constitute a compact medium but a well deformable layer that crushes and compacts itself under blast, absorbing a large amount of energy in internal compaction and deformation work.

Extensive full-scale testing has corroborated the above facts.

## 4. CONCLUSIONS

The EXP range of doors presents a unique concept in the design of door panels to resist the effects of placed or hollow charges.

The design is ingenious in its simplicity and the constitutive materials are elementary and inexpensive.

The validity of the various designs has been confirmed by multiple full-scale tests.

Combined protection against 50lbs of high explosive and RPG7 is easily achieved.

Some examples of door panels are schematically presented overleaf in Figures 1, 2, and 3.

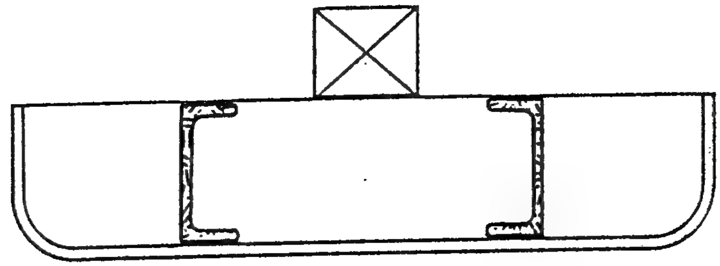

Fig. 1 Spaced steel plate door panel for standard charges.

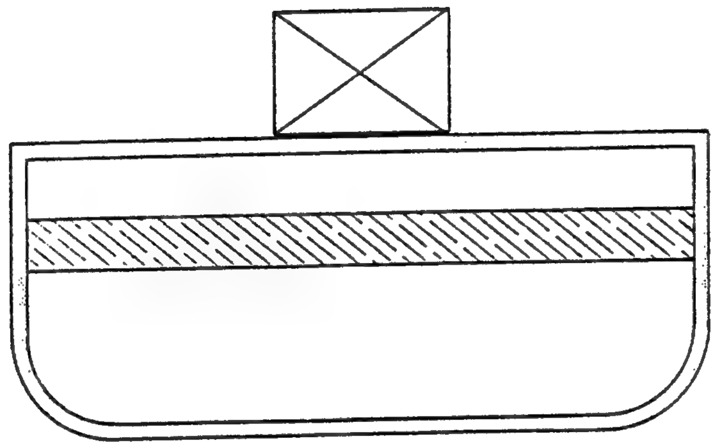

Fig. 2. Membrane door panel for heavy charges.

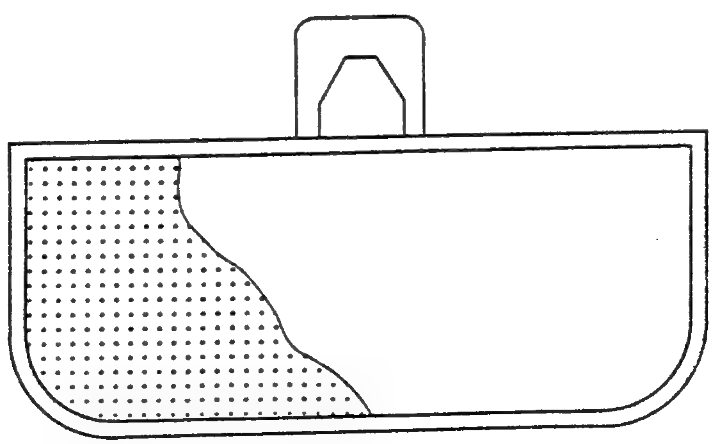

Fig. 3. Membrane door panel for heavy and shaped charges.

SECTION 08315

BLAST RESISTANT DOORS

*NOTES TO THE SPECIFIER*

*This sample spec is for blast doors only. There is a separate sample spec for pressure doors.*

PART 1 - GENERAL

1.1 DESCRIPTION

A. Work included: Provide blast resistant door systems where shown on the Drawings, as specified herein, and as needed for a complete and proper installation.

B. Related work:
   1. Documents affecting work of this Section include, but are not necessarily limited to, General Conditions, Supplementary Conditions, and Sections in Division 1 of these Specifications.

*Throughout Part One carefully use the standard wording of other Sections in the Project Manual.*

1.2 QUALITY ASSURANCE

A. Use adequate numbers of skilled workmen who are thoroughly trained and experienced in the necessary crafts and who are completely familiar with the specified requirements and the methods needed for proper performance of the work of this Section.

B. Use a subcontractor who has been engaged in the manufacture of blast resistant door systems for at least five years immediately prior to the start of this Work, and who has a history of successful production acceptable to the Architect.

*Insist upon this as a minimum length of experience.*

C. Provide written confirmation that the manufacturer has established and maintains formal quality assurance and quality control procedures, including written policies on 100% inspection of all materials and fabrication steps that could affect safe operation of the unit at required performance levels.

D. Except as otherwise approved in advance by the Architect, provide work of this Section designed and furnished by one manufacturer, factory-assembled, completely operable, and shipped as a unit.

E. In addition to complying with pertinent requirements of governmental agencies having jurisdiction, design the work of this Section to comply with pertinent recommendations contained in the following.
   1. "Design of Blast-Resistant Construction for

Atomic Explosions", by C. S. Whitney, B. G. Anderson, and E. Cohen, Journal of the American Concrete Institute, March 1955.
2. "The Effects of Nuclear Weapons", U. S. Government Printing Office, Washington, D. C., 1964.
3. "Structures to Resist the Effects of Accidental Explosions", Department of the Army, the Navy, and the Air Force, June 1969.
4. "Structural Design for Dynamic Loads", Norris, Hansen, Holley, Biggs, Namyet, and Minami, McGraw-Hill Book Company, 1959.
5. "Formulas for Stress and Strain", 5th Edition, R. J. Roark and W. C. Young, McGraw-Hill Book Company, 1975.
6. "Design of Structures to Resist Nuclear Weapons Effects", American Society of Civil Engineers, Manual Number 42, 1961.
7. "Manual of Steel Construction", 7th edition, of the American Institute of Steel Construction.

1.3 SUBMITTALS

A. Comply with pertinent provisions of Section 01340.

B. Product data: Within 35 calendar days after the Contractor has received the Owner's Notice to Proceed, submit:
1. Materials list of items proposed to be provided under this Section;
2. Manufacturer's specifications and other data needed to prove compliance with the specified requirements;
3. Shop Drawings in sufficient detail to show fabrication, installation, anchorage, and interface of the work of this Section with the work of adjacent trades;
4. Calculations, showing conformance with the stipulated pressure design and loading requirements;
5. Manufacturer's recommended installation procedures which, when approved by the Architect, will become the basis for accepting or rejecting actual installation procedures used on the Work.

C. Provide operation and maintenance manuals compiled in accordance with the provisions of Section 01730 of these Specifications.

1.4 PRODUCT HANDLING

A. Comply with pertinent provisions of Section 01640.

**08315** **Monograph and Specifications for**

# Blast Resistant Doors

By
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MANUFACTURING CO.

Ever since the invention of gunpowder we've had to worry about adequate protection against devastating blasts. No matter whether the blasts were accidental—from contact of the tiniest spark with some volatile material—or part of a controlled series of research-associated or production-associated operations, the tragic loss of lives and facilities simply had to be reduced.

Except for its staggering results, very little was known about the nature of explosions until the mid 1950's. Now we know a great deal, and we learn more everyday it seems. There's a growing mountain of knowledge about the reaction of various materials under various situations; an entire generation of engineers has specialized in developing means for securing adequate protection; today it is possible to drastically reduce loss of life and damage to facilities under blast conditions.

But sadly, the new knowledge and ability has grown more rapidly than the awareness that it exists. So we see hazardous facilities being designed even today without safety provisions which could have been incorporated easily and at relatively little expense.

Now a discussion of blast resistant doors becomes unavoidably technical, and there are a few items and concepts one doesn't encounter everyday. But when explosions can be expected to occur in a facility there is no way to secure adequate protection without incorporating state-of-the-art equipment, so it is important for designers to understand the basics of today's protection.

For instance, the first and most important criterion of blast resistant door design is to determine whether one really has a blast resistant door application. Let's talk about that for a moment.

The terms "blast resistant door" and "pressure resistant door" are used sometimes as though they were synonymous, which they are not. Each is a separate design task and warrants being treated as such. To specify a blast resistant door where a pressure resistant door is required, or vice versa, can be extremely hazardous.

## Pressure Resistant Doors

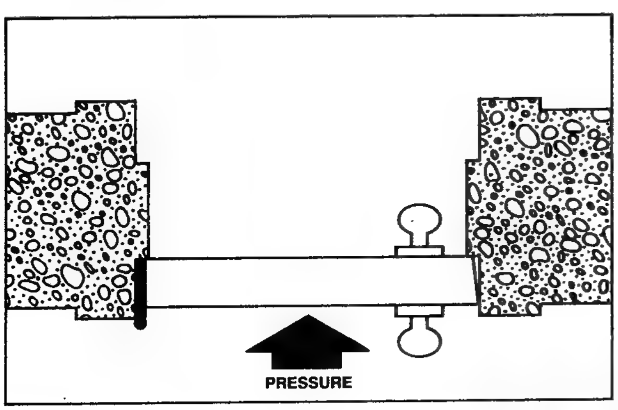
A typical example of a pressure resistant door application is found in an air lock where negative or positive air pressures exist for control purposes such as in a clean room. A pressure resistant door is normally defined as:

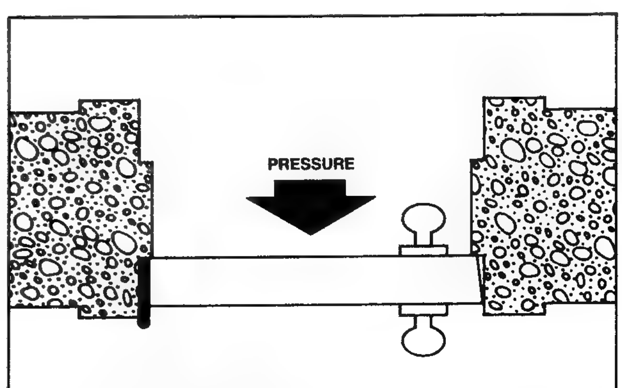
> "A door where a positive or negative pressure loading (above or below atmospheric pressure) is applied over a *long* duration (expressed in seconds, minutes, or longer), and where the pressure loading decays (is removed from the door) over a *long* duration."

With durations of such length the loads can be considered static, and the doors can be designed accordingly. The dynamic response of the door is not considered for this type loading.

If the door is positioned so that the pressure loading acts to seat the door *into* the frame *against* the stops, no consideration need be given to the hardware other than it be sufficient to support the weight and size of the door.

However, if the pressure acts to *unseat* the door *away* from the stops, then the hardware must be capable of resisting all loads imposed



by the pressure as well as radial and thrust loads. This is an important consideration in the design of both pressure resistant and blast resistant doors, and it has led to the design of special hinges and locking devices.[NB]

Blast resistant doors, on the other hand, are normally designed to resist a high pressure shock front of very short duration (expressed in milliseconds) which expands outward from the center of the detonation, with intensity of the pressures decaying with distance and as a function of time: The exception to this is for nuclear blasts where long durations (in seconds) are common.

When a detonation occurs, there is a violent release of energy in a gaseous medium. This gives rise to a sudden pressure increase in that medium. The pressure disturbance is termed a "blast wave", and it is characterized by an almost instantaneous rise from the normal or "ambient" pressure to what we call a "peak incident over-pressure".

This pressure increase—or "shock front"—travels rapidly from the burst point with a velocity which will be diminishing but which will remain in excess of sonic velocity of the gaseous medium.

The nature of the shock wave varies according to several factors, not the least of which derive from the type of "burst" experienced. We can classify the bursts into "free air bursts", "air bursts", "surface bursts", "partially confined", and "confined". In all types of bursts the door will be engulfed by the shock pressures as the wave front impinges on the structure. The magnitude and distribution of the blast loads on the door, rising from these pressures, are a function of the explosive properties.

These consist of:

a. Type of explosive material;
b. Its energy output;
c. Weight of the explosive;
d. Location of the explosive relative to the door.

The blast wave pressure is also increased due to reflection and reinforcement by its interaction with the ground area or the structure in which the door is installed.

[NB]See separate monograph on Pressure Resistant Doors which covers this subject in greater depth.)

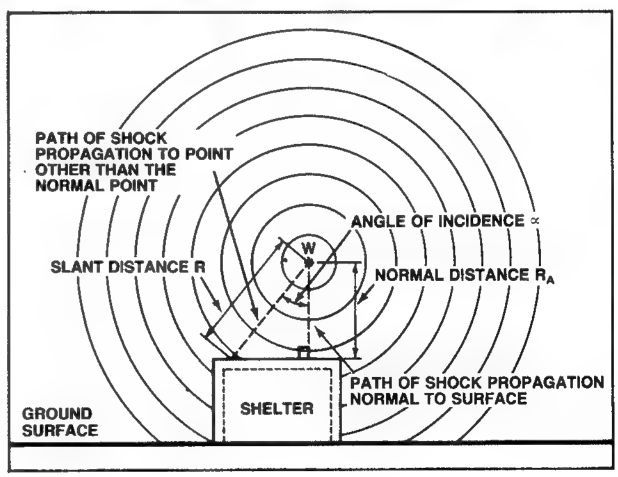
## Free Air Bursts

When a detonation occurs adjacent to—and above—a protective structure, and so near that no amplification of the initial shock wave occurs between the explosion source and the door, then the blast loadings acting on the door are defined as "Free air burst blast pressures".

As the pressure wave moves radially away from the center of the explosion, it contacts the door and—upon contact—the initial wave pressures are reinforced and reflected.

The variation of the pressure on the door surface is a function of the "angle of incidence":

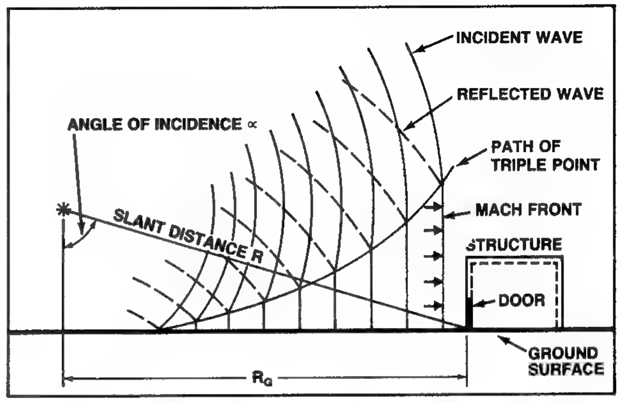
The angle of incidence is formed by a line which defines the normal distance between the point of detonation and the door, and a line which defines the path of shock propagation between the center of the explosion and any other point of the structure in which the door is located.



## Air Bursts

An "air burst" blast environment is produced by detonations which occur above the ground surface and at some distance away from the door, so that the initial shock wave propagating away from the explosion impinges on the ground surface prior to its arrival at the door.

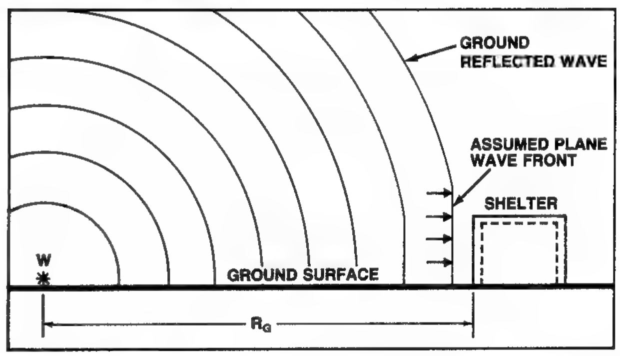
As the blast wave continues to propagate outward, a front known as the "mach front" is formed by the interaction of the initial wave and a reflected wave which resulted from reinforcement of the incident wave by the ground. The height of the mach front increases as the wave propagates away from the center of the detonation. This increase in height is referred to as the path of the triple point and is formed by the intersection of the initial reflected and mach waves. A structure is subjected to a plane wave (uniform pressure) when the height of the triple point exceeds the structure height.




## Surface Burst

A charge located on the ground surface—or very near to it—is considered to be a "surface burst".

In a surface burst, the initial wave of the explosion is reflected and reinforced by the ground surface to produce a reflected wave. Unlike the air bursts, the reflected wave merges *with* the incident wave at the point of detonation. This forms a single wave similar in nature to the reflected wave of the air burst, but essentially hemispherical in shape.




## Partially Confined Explosions

When an explosion occurs within a structure, the peak pressures associated with the initial shock front are extremely high and are amplified by their reflections within the structure. Additionally, the accumulation of gases from the explosion exert more pressures and they increase the load duration within the structure. The combined effects of both pressures can destroy a structure unless adequate venting is provided.

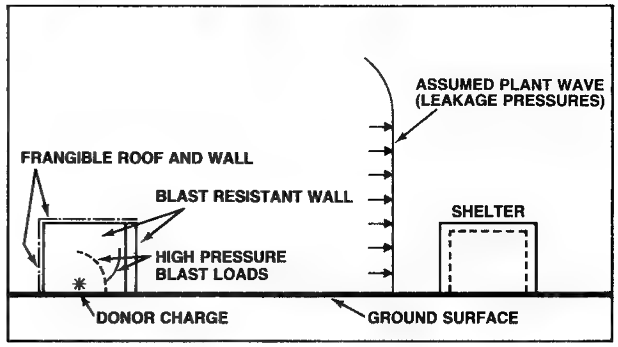
The use of cubical type structures with one or more surfaces either sufficiently frangible or open to atmosphere will normally provide adequate venting. This type of structure permits a blast wave from an internal explosion to spill over onto the exterior ground surface in a condition known as "leakage pressure".

Exterior, or leakage pressure loads result when the detonation occurs near the ground surface and behind an obstruction which interferes with the shock wave before it reaches the door.

Interior, or high pressure loads result when the detonation is located within—or immediately adjacent to—a structure, and blast pressures are amplified due to multiple reflections by the structure as a result of its closeness to the explosion. The pressures reflected and reinforced within the structure are referred to as

"interior shock front pressures", while those pressures accumulated from the gaseous products of the explosions are identified as "gas pressures".

The term "frangible" pertains to those elements of a structure whose strength and mass or anchorage are sufficiently weak to minimize the amplification of the shock front pressures and reduce confinement of the explosive gases by breaking up, falling away, or opening slightly to provide relief of pressure.




## Unconfined Explosions

We previously defined free air bursts, air bursts, and surface bursts. Of those categories, air bursts are seldom encountered and a free air burst is the least likely to occur.

**Free air burst loads:** For this type loading the blast wave propagates away from the center of the explosion, striking the door without intermediate amplification of the initial shock wave.

**Air burst loads:** For this type loading the explosion is located at a distance away from and above the door so that the ground reflections of the initial wave occur before the blast wave reaches the door.

**Surface burst loads:** For this type loading the explosion is located close to—or on—the ground so that the shock wave is amplified at the point of detonation due to ground reflections.

## Protection Categories

Protection afforded by a door and the facility in which it is installed is subdivided into four protection categories:

**Class A protection:** Provides life safety; protects personnel from fragments, falling portions of a structure or equipment; attenuates blast pressures and structural motion to a level consistent with safety requirements.

**Class B protection:** Protects equipment and supplies from fragment impact, blast pressures, and structural motions; protects against uncontrolled release of hazardous materials including toxic chemicals, radioactive materials, biological materials, and similar items.

**Class C protection:** Protects against communication of detonation by fragments and high blast pressures.

**Class D protection:** Protects against mass detonations of explosives as a result of sympathetic detonations produced by communication of detonation between two adjoining areas.

## Fragmentation

In some situations, primary fragments from cased explosives can be, depending upon their mass, the controlling factor in the design of a blast-resistant door. The mass velocity characteristics of the primary fragments also depend upon the properties of the explosive.

Heavy high velocity primary fragments may penetrate a door, depending upon its thickness and other characteristics, while lightweight fragments seldom achieve penetration. However, both light and heavy fragments may richochet into protected areas and cause injury to personnel, damage to equipment, or detonation of other explosives.

For protection against primary fragments, a sufficient structural thickness must be provided to prevent full penetration.

## Explosive Materials

Explosive materials are classified according to their physical state, which consists of solids, liquids, and gases.

Solid explosives are primarily high explosives. However, other materials such as chemicals and propellants also can be classified as potentially high explosive materials.

The blast pressure environment produced will vary among different solid explosive materials, and also can vary for a particular material. The blast effects of solid materials (which consist of the blast pressure impulse, durations, and other effects) have been well established and charted and are often stated as to their equivalence in pounds of TNT.* See Bibliography notations.

The explosive properties of such materials determine limitation of the detonation process and, thereby, result in either high order or low order detonation. With high order detonation the process is generally complete and results in a maximum pressure output for any given type and amount of material. If the detonation is incomplete, a large quantity of explosive is consumed by deflagration (a sudden and violent combustion), thus reducing blast pressure.

Unlike high explosive materials, other solid, liquid, and gaseous explosive materials exhibit variations of their blast pressure output due to the fact that an explosion of these materials in many instances is incomplete, with only a portion of the total mass involved in the detonation process. The remainder of the mass usually is consumed by deflagration with a large amount of the material's energy being dissipated in thermal energy.

## Designing Blast Resistant Doors

Now if all this information seems complicated and confusing, it's because the entire task of designing a blast resistant door system is complicated and confusing. And if the topics discussed appear to warrant much deeper discussion, it's because a complete treatise on blast resistant door systems would fill many volumes.

There is no such thing as a "stock or standard" blast resistant door, simply because there are no stock blast situations to protect against. Each installation invariably presents new challenges, new parameters of explosives and distance, and combined hazards from inside and out. True expertise in designing successful blast resistant door systems derives only from years of experience and considerable special training for the entire design/build team.

The variables are so numerous that highly sophisticated computer programs are used today to arrive at practical solutions. And only the most competent and qualified specialists can be expected to turn the solutions into operating reality. Since these solutions frequently impinge on other structural components of a facility, it is wise to tackle preliminary design of the blast resistant door systems early in the design stage of any project where their need will exist.

While blast resistant door systems may be required in many high technology industrial buildings, as well as military applications, project designers of those buildings cannot be expected to have the specialized knowledge needed to completely plan for an adequate blast resistant installation. So it is important to establish an early relationship with a reputable blast resistant door manufacturer to avoid expensive redesigns and project delays.

Data the manufacturer's will need start with the type and amount of explosive involved, the type blast to be anticipated, and the construction in which the blast resistant door systems must be located. These three are only the starting point; the rest is up to the specialists.

But if you want to be truly helpful in design of the door system, determine all pertinent information needed to fill in the blanks on the following list. You will speed up the process if you do.

## Seven Questions to be Considered and Answered

1. Is design analysis to be dynamic? _______ or static? _______
2. If static analysis, the maximum blast loading that door will be subjected to in _______ psi or _______ psf.
3. If dynamic analysis, one of the following combinations of data must be furnished, using these definitions:
"W" is known load in equivalent pounds, tons, Kton, or Mton of TNT.
"r" is slant distance from the explosion in feet.
"$T_o$" is the duration of the positive pressure in seconds or milliseconds.
"$P^pfa$" is peak free air pressure in psi.
"$P_sP$" is peak incident pressure (reflected pressure in psi).

3.1 W _______ , r _______
3.2 W _______ , $T_o$ _______
3.3 W _______ , r _______ , $T_o$ _______
3.4 W _______ , $P^pfa$ _______ , $T_o$ _______
3.5 $T_o$ _______ , $P^pfa$ _______
3.6 r _______ , $P^pfa$ _______
3.7 r _______ , $P^pfa$ _______ , $T_o$ _______
3.8 $P_sP$ _______ , $T_o$ _______
3.9 $P_sP$ _______ , r _______
3.10 $P_sP$ _______ , r _______ , $T_o$ _______
3.11 W _______ , $P^pfa$ _______ , r _______

4.0 If dynamic analysis, the following data must also be provided:
4.1 Angle of incidence in degrees (If this data not available, assume 0° angle, which provides maximum pressure).
4.2 If atmospheric blast, specify if air _______ or surface burst _______.
4.3 If confined or partially confined blast, furnish sketch showing dimensions of room or test cell including height, locations of door and explosion, confined gas pressure in psi and duration of gas pressure in seconds _______ or milliseconds _______.
5.0 The following data is required for either dynamic or static analysis:
5.1 Direction of initial blast force:
5.1.1 To seat door _______
5.1.2 To unseat door _______
5.2 Is plastic (permanent) deformation permitted? (not permitted for static design)
5.2.1 Ductility ratio _______ or
5.2.2 Total permissible deflection _______ or
5.2.3 Degrees of rotation _______
5.3 Allowable elastic deflection _______. Unless otherwise specified, doors normally are designed with deflection limited to L/60 for all components.
5.4 Door must be designed for 100% rebound pressure when static analysis is used. For dynamic analysis door will be designed for rebound as determined by the dynamic response.
6. What level of blast protection is required: A_______ B _______ C _______ or D _______ ?
7. If additional requirements such as fire rating, security, shielding or acoustical performance are required please list.

## Bibliography


1. Design of Blast Resistant Construction for Atomic Explosions C.S. Whitney, B.G. Anderson and E. Cohen—Journal of the American Concrete Institute, March, 1955.
2. The Effects of Nuclear Weapons—U.S. Government Printing Office, Washington, D.C. 1964.
3. Structures to Resist the Effects of Accidental Explosions—Department of the Army, the Navy and the Air Force, June 1969.
4. Structural Design for Dynamic Loads—Norris, Hansen, Holley, Biggs, Namyet and Minami, McGraw-Hill Book Company, Inc., 1959.
5. Formulas for Stress and Strain, 5th Edition, R.J. Roark and W.C. Young, McGraw Hill, Inc. 1975.
6. Design of Structures to Resist Nuclear Weapons Effects, American Society of Civil Engineers, Manual Number 42, 1961.
7. Manual of Steel Construction, 8th Edition, of the American Institute of Steel Construction.

## 1.5 WARRANTY

A. Upon completion of the work of this Section, and as a condition of its acceptance, deliver to the Architect two copies of a written warranty signed by an Officer of the manufacturing company and providing at least two year warranty against defects in material and workmanship.
   1. Exclude damage due to fair wear and tear, extraordinary usage, irregular use, improper operation or maintenance, deliberate abuse, mechanical damage, vandalism, fire, earthquake, and similar casualty and defects caused by excessive or uncontrolled internal or external pressures.
   2. Limit the liability to repair-in-place of defects, or replacement, and exclude damages due to loss of profit and consequential damage.

*This is the standard warranty issued by Overly. It is your assurance of quality workmanship.*

# PART 2 - PRODUCTS

## 2.1 DESIGN

A. Design is based on using blast resistant door systems manufactured by Overly Manufacturing Company, Greensburg, Pennsylvania 15601 (412) 834-7300, and proprietary products and methods of that company may be described herein. Provide the products upon which the design is based, or provide equal products approved in advance by the Architect.

B. Prepare complete engineering design in accordance with the dimensions and arrangements shown on the Drawings.
   1. Comply with pertinent requirements of all governmental agencies having jurisdiction.
   2. Secure all required design approvals prior to submittal of data described in Paragraph 1.3-B above.
   3. Affix the signature and verification of the engineer on all design data submitted to the Architect.

C. Design the doors to be constructed of steel plates on both faces, internally reinforced, and having the appearance of conventional flush metal doors.

2.2 DESIGN CRITERIA

A. Design criteria:

1. Provide (dynamic) (static) design analysis.

   a. Use the following combination of data:

*Only one of the listed combinations is required to enable the door to be properly designed.*

$W$__________, $r$__________

$W$__________, $T_o$__________

$W$__________, $r$__________, $T_o$__________

$W$__________, $P^P$fa__________, $T_o$__________

$T_o$__________, $P^P$fa__________

$r$__________, $P^P$fa__________

$r$__________, $P^P$fa__________, $T_o$__________

$P_sP$________, $T_o$__________

$P_sP$________, $r$__________

$P_sP$________, $r$ __________, $T_o$__________

$W$__________, $P^P$fa________, $r$__________

   b. Angle of incidence in degrees____________.

(Option #1)

   c. Atmospheric blast (air) (surface)

(Option #2)

   c. Confined blast, in the space shown on the Drawings, with:
      (1) Confined gas pressure in psi of_____;
      (2) Duration of gas pressure in (seconds) (milliseconds) of________.

(Option #3)

   c. Design for maximum blast loading of (__________psi) (__________sf)

2. Direction of initial blast force (to seat door) (to unseat door).

(Option A)

3. Permanent plastic deformation is not permitted.

(Option B)

3. Permanent plastic deformation is permitted as follows:
   a. Ductility ratio of __________.

*Permitted only with dynamic analysis of the door.*

(Option B-1)

   a. Total permissible deflection of __________.

*L/60 is standard.*

(Option B-2)

   a. Degrees of rotation of __________.

(End of Option B)

4. Allowable elastic deflection of __________.
5. Rebound pressure of __________.
6. Fire rating of __________.
7. Bullet resistance of __________.
8. Acoustical performance of __________.

*If static analysis is used, specify rebound to be 100%. For dynamic analysis, specify rebound to be calculated based on dynamic response of the door.*

2.3 MATERIALS

B. Construct the door systems from the following products, or equals approved in advance by the Architect.
   1. Steel plate 3/16" or greater in thickness:
      a. Comply with ASTM A36.
   2. Steel sheets less than 3/16" in thickness:
      a. Comply with ASTM A607.
   3. Structural shapes 2-1/2" x 2-1/2" or less in dimension:
      a. Comply with AISI M1020.
   4. Structural shapes larger than 2-1/2" x 2-1/2":
      a. Comply with ASTM A36.
   5. Bars, rounds, and flats:
      a. Comply with AISI 1018.
   6. Perimeter framing members, and embedments receiving hinges or locking pins:
      a. Fabricate from formed steel plate shapes or rolled structural shapes.
   7. Hardware and sealing devices:
      a. Provide only corrosion-resistant latching devices.
      b. At exterior doors:
         (1) Provide either single-point or multi-point locking devices as required by the blast loads, operated by lever

*Overly standard device is specified.*

*Locking device also can be provided with panic bar operation from interior side.*

handles from both sides;
(2) Provide keyed cylinder on exterior side to lock outside lever handle;
(3) Permit entry by key only, with egress by lever handle at all times.

c. Make all latches adjustable, self-cleaning, and with full bolt penetration to develop maximum resistance.

d. Equip hinges with radial bearings, thrust bearings, and grease fittings.

*All outside trim can also be eliminated with operation only from interior side.*

8. Glass viewing port:
   a. At exterior doors used for routine entrance/exit, provide glass viewing panel not larger in size than one sq ft.
   b. Provide, as a minimum, double laminated clear safety glass with energy absorption capacity, prior to collapse, of more than twice that required to resist the blast loading.

## 2.4 OTHER MATERIALS

A. Provide other materials, not specifically described but required for a complete and proper installation, as selected by the Contractor subject to the approval of the Architect.

## 2.5 FABRICATION

A. General:
   1. Assemble the work of this Section using all welded construction conforming to pertinent requirements of AWS D1-1.
   2. Fabricate the work of this Section in strict accordance with the approved Shop Drawings and with pertinent requirements of governmental agencies having jurisdiction.

B. Painting and cleaning:
   1. On surfaces which are inaccessible after assembly, apply protective coating of rust-inhibitive primer or other appropriate protection approved in advance by the Architect.
   2. After assembly, and prior to inspection, thoroughly clean all surfaces.
   3. After inspection, and completion of repairs and revisions required by the inspection, apply a shop coat of rust-inhibitive primer to exposed surfaces where so called for on the approved Shop Drawings.
   4. At exposed machine-finished surfaces, thoroughly clean and coat with a rust-preventative approved in advance by the Architect.

## PART 3 - EXECUTION

### 3.1 SURFACE CONDITIONS

A. Examine the areas and conditions under which work of this Section will be performed. Correct conditions detrimental to timely and proper completion of the Work. Do not proceed until unsatisfactory conditions are corrected.

### 3.2 INSTALLATION

A. Install the work of this Section in strict accordance with the approved Shop Drawings and pertinent requirements of governmental agencies having jurisdiction, positioning all components plumb, level, square, firmly anchored into position, and operating in accordance with the design criteria.

B. Pay such costs as are required, and secure a visit to the job site by a qualified representative of the manufacturer who shall:

*Highly desirable to eliminate future callbacks.*

1. Inspect the completed installation;
2. Put all components of the work of this Section through at least ten complete cycles of operation, verifying that each component is properly installed and properly operating, and making required adjustments to achieve optimum operation.
3. Direct the efforts of the Contractor in correcting improper installation of the work of this Section; and
4. State in a signed letter to the Architect that the work of this Section has been installed in complete accordance with the approved Shop Drawings.

### 3.3 PAINTING

A. Provide painting of the work of this Section as part of the work of Section 09900 of these Specifications.

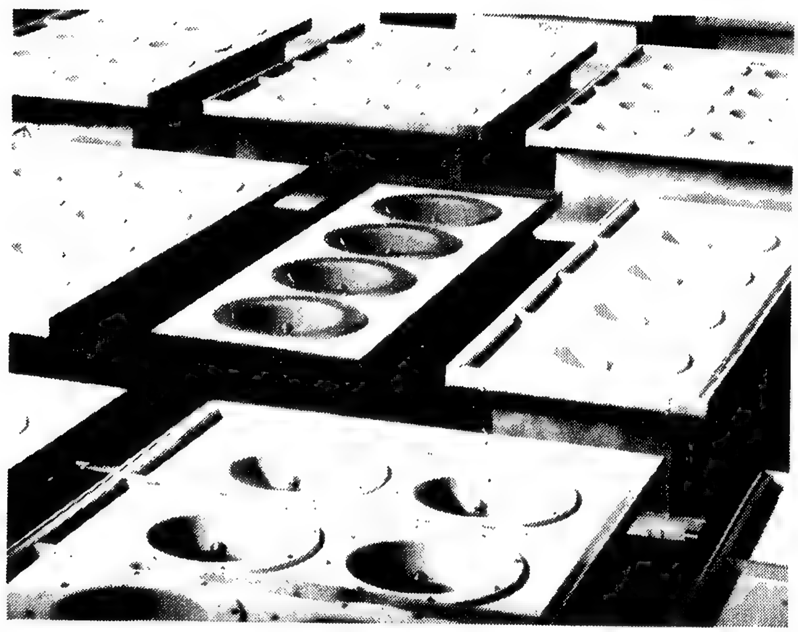
### 3.4 INSTRUCTION

A. Instruct the Owner's maintenance personnel regarding the contents of the operation and maintenance manual required to be submitted under Article 1.3 of this Section.

END OF SECTION

Temet USA, Inc.

# Engineered Blast Protection for Military Facilities



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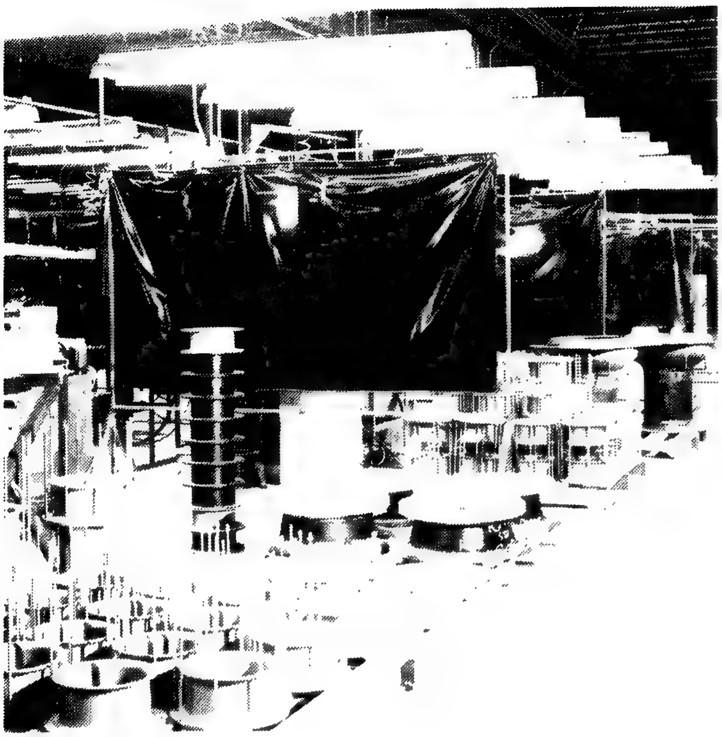
# Advancing the science of



With over 10 different models of blast valves, each available in multiple configurations, Temet USA can provide engineered solutions to specific blast protection requirements.

## With systems engineered for today's requirements.

Temet USA, Inc. designs and manufactures protective equipment for blast-hardened military structures and other critical military and civilian installations such as hospitals and nuclear power facilities.

Our specialized products include blast valves, blast doors, and gastight valves and doors engineered to save lives and protect vital systems against the levels of threat confronting military installations, including highly accurate conventional weapons.

From our corporate and engineering offices minutes from Washington, D.C., and our manufacturing plant located in Cincinnati, Ohio, we design, produce, and deliver equipment that represents the state-of-the-art in military blast protection.

# military blast protection.

*Prior to painting, all products are shot blasted to 100 percent white metal to assure minimum 20-year service life.*

*AWS-certified welders produce weldments to close tolerances.*

## Technologies proved around the world...

## improved in the United States.

We've selected as the basis for our comprehensive product line equipment originally developed by the Finnish firm Temet Oy. Our thorough evaluation determined these products—the result of some 30 years of experience—to be closest to the needs of U.S. and its allied forces in strength, quality, simplicity, and reliability.

By our exclusive license agreement, Temet USA manufactures Temet Oy products in the United States. This enables Temet USA to take advantage of well-established blast protection research and development.

We have complete engineering freedom to modify and further upgrade these superior products to meet today's military requirements. This we have accomplished by drawing upon our professional staff's extensive, direct involvement in design and construction of all types of large above- and below-ground blast-hardened military structures.

Their talents have produced the unique Temet USA approach to military blast protection. We help facility designers define and calculate the threat criteria, so that we can provide the appropriate grades of our standard valves or doors—singly or in any combination—to achieve the optimum in form, fit, and function. The result: each project is a custom-engineered solution without the typical high costs of custom engineering.

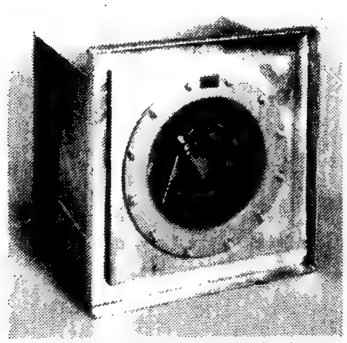
*Integral door and frame assemblies are tested for functionality before shipment.*

# The most extensive research effort in the field.

We call on years of experience in international trade and manufacturing management to assure timely completion and delivery on every project.

By pursuing an aggressive program of research and development, leading to a better understanding of blast effects, Temet is better able to enhance systems of current design and to develop the new blast protection products for the coming decades.

Temet R&D, for example, has resulted in blast valves designed specifically for the high pressure, short duration conventional weapons threat criteria of the 1980s. These valves can effectively attenuate blast waves of 1 ms or less up to 125 bar (1,812 psi). Recent tests have demonstrated that even at 0.64 ms, 1812 psi, our PV-120-300 valve reduced pass through side on pressure and impulse to 22 psi and 16.2 psi-ms.



PV-120-300 high pressure blast valve is a direct result of Temet USA research and development.

## Helping designers and builders of blast-hardened military structures.

Because the specific level of threat can vary from location-to-location within a single facility, Temet blast protection equipment offers a broad range of performance characteristics. Facility designers working with Temet can therefore achieve custom-engineered solutions based on equipment of standard design.

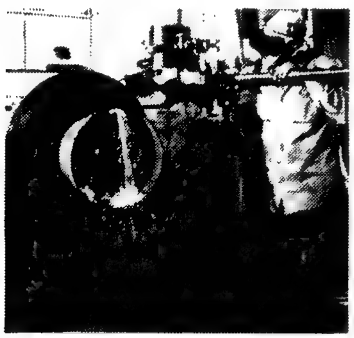
However, when the need arises, we're ready to develop new or special-application equipment to solve a particular problem.

As important as our ability to help facility designers achieve blast protection objectives is our understanding of the needs of contractors who build military structures. That's why we have made our systems easy to install. Temet blast valves

000908

# and development

and blast doors arrive on-site fully assembled and ready for placement into walls and attachment to a structure's reinforcing steel before concrete is poured. When the concrete has set and the forms are removed, the valve or door is permanently in place.



*Custom fabrication of PV-6-250-SL valve housing.*

## Protecting lives and equipment.

The purpose of blast protection equipment is to minimize or eliminate the destructive effects of the extreme over- and underpressure waves produced by an explosion.

Installed in the walls of a protected facility, blast valves shut within milliseconds of sensing these high pressure conditions, then reopen just as rapidly so that air for breathing and air-cooled equipment is interrupted for the least possible amount of time.

Valves can also be installed in the exhaust pipes of emergency diesel-generators, to prevent damage to this equipment. Under attack of conventional weapons, valves may close and reopen many times within a few seconds.

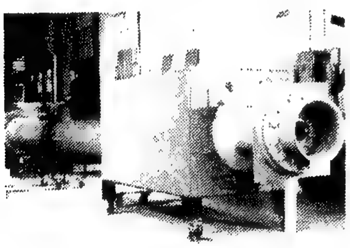
Some applications may require valves that lock and seal; for example in locations where the design objective is to confine an explosion inside a facility.

# Whatever the need or antic
# an engineered solution.

All Temet USA blast protection products are manufactured in our Cincinnati, Ohio, plant by our own permanent production staff. Ours is a facility and organization dedicated to the production of engineered military blast protection equipment.

These products are manufactured in compliance with a quality control system based on our ASME Quality Control System for Unfired Pressure Vessels and applicable ASTM, AISC, and ANSI/AWS standards.

Performance has been verified in independent laboratory shock tube tests. Every valve delivered is subjected to air flow, pressure drop, and spring tests to assure quality. All valves that lock and seal are tested for leak tightness.

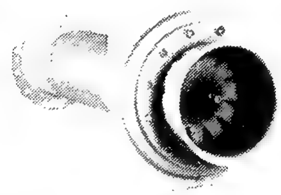


*Air flow pressure drop testing station.*

**Modular Valves**
No attenuation chambers required.

In-wall modules of from one to 10 valves per module with single units of up to 50 valves. With structural steel support, modules can be assembled to create valve walls.

PV-60-200
910 scfm, 60 bar short/20 bar long
PV-120-300
1,865 scfm, 125 bar short/26 bar long



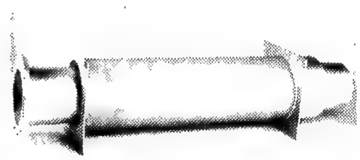
**Single Valves**
Attenuation chambers required.

For wall or pipe mounting.

PV-6-350
4150 scfm, 34 bar short/18 bar long
PV-6-250
2150 scfm, 25 bar short/18 bar long
PV-6-150
520 scfm, 25 bar short/18 bar long

**Engine Exhaust Valves**
Designed to protect diesel-generators from damaging effects of blast waves.

PVD-250
6000 acfm @ 1200°F, 25 bar short/18 bar long
PVD-150
1800 acfm @ 1200°F, 25 bar short/18 bar long



*Matching wall sleeves are furnished with all engine exhaust valves.*

**Gas Protection Doors**
Temet gas protection doors are essentially lightweight, gasketed blast doors, offering extremely low leakage rates. As long as the facility's ventilation system can maintain even a small positive pressure no war gases will enter.

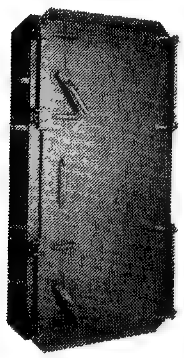
# ipated threat, Temet has

**Self Latching Valves**
Automatically lock and seal in the closed position to prevent escape of explosive or toxic combustion products.

Two versions are available: the standard unit with a metal-to-metal seat, and a neoprene gasketed version with even lower leakage rates.

This series of valves is available in a variety of configurations to adapt to each application. Contact us for assistance in solving your needs for self latching valves.

PV-6-350 SL, SLG
PV-6-250 SL, SLG

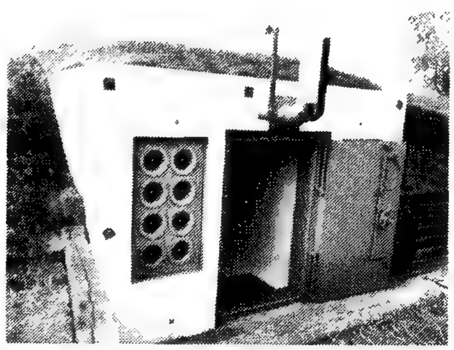


**Blast Doors**
While designed to resist the specific pressure, duration, and impulse at each location, blast doors can be grouped into three basic pressure classes. All door plates are solid steel and doors are delivered to the site completely assembled.

| | |
|---|---|
| Type S-1 | to 3 bar |
| Type S-3 | 3 bar to 10 bar |
| Type S-6 | over 10 bar (up to 690 bar) |

Organizations around the world have approved the use of Temet USA engineered blast protection products in facilities they operate or in facilities built under their supervision.

U.S. Army Corps of Engineers, Waterways Experiment Station
U.S. Army Corps of Engineers, European Division
U.S. Army Corps of Engineers, Middle East Division
U.S. Army Corps of Engineers, Far East Division
U.S. Navy Facilities Engineer Command, OICC Mediterranean
U.S. Navy Facilities Engineer Command, Atlantic Division
U.S. Navy Civil Engineering Laboratory
U.S. Air Force, Europe
U.S. Air Force, Logistics Command
U.S. Air Force, Headquarters Strategic Air Command
U.S. Air Force, Engineering Services Center
U.S. Air Force, Space Command
Department of Energy, PANTEX, Nuclear Weapons Assembly Facility
Department of Energy, Johnston Island Chemical Agent Disposal System
Lawrence Livermore National Laboratories
Los Alamos National Laboratories
Hercules Aerospace Bacchus Works
Arabian American Oil Company
Kuwait National Petroleum Company
Royal Saudi Arabian Air Force
Royal Saudi Arabian Naval Forces
Saudi Arabian Ministry of Defense and Aviation
Republic of Korea Air Force



*Typical use of Temet USA blast valves and blast doors in military application.*

# Specify
# Temet USA.

If you are designing or building a new blast-hardened facility, Temet USA is ready to provide an engineered solution, just as we have on projects worldwide.

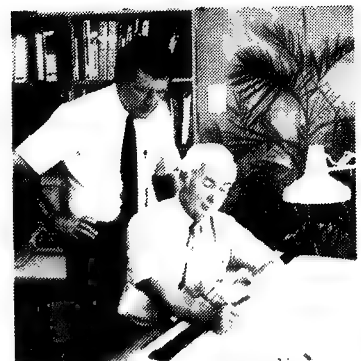
And only Temet is dedicated exclusively to meeting the requirements of the military community.

Today, we provide the highest quality military blast protection equipment available: Designs which have evolved over 30 years, and have been specialized for the U.S. military through more than five years of our own development, based on our collective decades of hands-on military facilities design, construction, and command experience.

That is why we are more than simply an equipment supplier. Temet USA is a full-service applications engineering, and production organization with capabilities extending to mechanical systems configuration, CBR filter systems, architectural layout of hardened facilities, and threat calculation.

If you would like to learn more about any of our engineered blast protection products, or want to discuss development of a specific application, we invite you to contact us by letter, phone, or Telex.

**Temet USA Inc.**
P.O. Box 439
Great Falls, Virginia 22066
USA
Telephone: 703/759-6000
TLX: 901932



*Military threat analysis and professional engineering capabilities are reflected in all Temet designs and applications.*

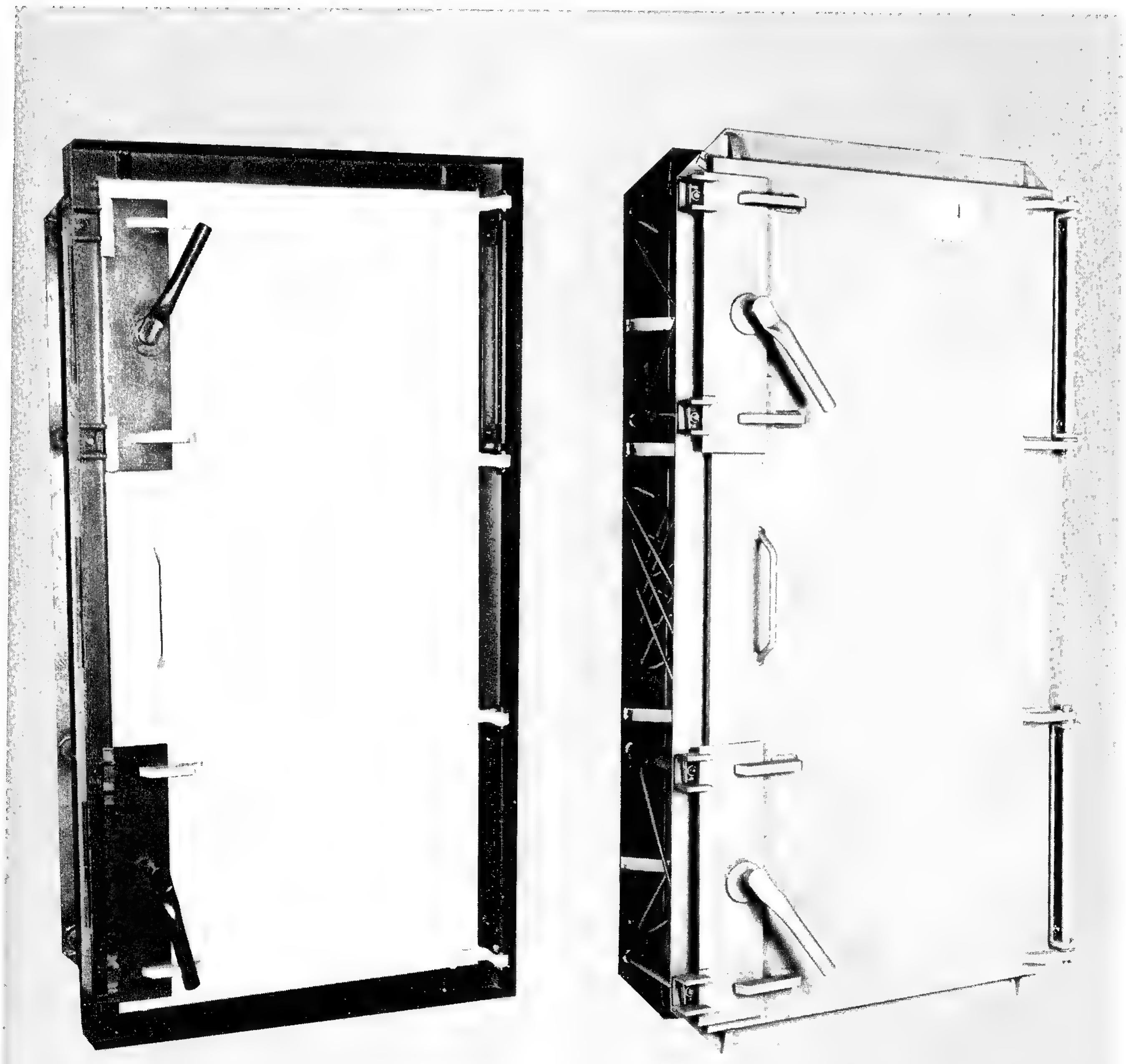
Printed in the U.S.A.


000912

# BLAST DOORS

Temet USA, Inc.

**STANDARDIZED BLAST DOORS FOR BLAST HARDENED MILITARY FACILITIES OR SIMILAR PROTECTIVE STRUCTURES. CONVENIENT CATALOG SELECTION INSTEAD OF COSTLY CUSTOM DESIGN.**



TUSA BD-84-0

## Door Type

Temet blast doors are fabricated from structural steel. Door plates are solid steel. Door frames are designed for installation in reinforced concrete walls. The door plate transfers blast forces directly to the door frame. Only rebound forces are taken through hinges and latches.

## Pressure Ranges

Temet standard doors are available in three ranges of static overpressure and rebound.

Model SO-1: 0 to 45 psi, 50% rebound
Model SO-3: 46 to 145 psi, 30% rebound
Model SO-6: 146 psi or higher

## Standard Sizes

U.S. sizes (free opening in feet) are 7 x 3 or 8 x 4 single and 7 x 6 or 8 x 8 double.

International sizes (free opening in millimeters):

| Single | Double | Hatches |
|---|---|---|
| 850 x 1850 | 3000 x 2500 | 600 x 800 |
| 850 x 2000 | 3000 x 3000 | 700 x 1200 |
| 1100 x 2000 | | |
| 1500 x 2000 | | |

## Door Frames

Standard door frames for all single SO-1 and SO-3 doors are recessed mount door plate type. All door hardware is within the frame. Concrete wall forms may be placed flush against the edges of the door frame. No cutouts to clear hardware are required.

Recessed mount frames are available as an option on SO-1 double doors.

SO-3 double doors and all SO-6 doors have surface mount door plates.

All frames are made to fit the wall thickness specified.

All SO-1 doors are available with an optional threshold flush with the finished floor.

## Installation

Temet blast doors and frames are shipped as completely assembled and tested single units ready to be installed in the wall form. This prevents alignment problems and eliminates field assembly work.

## Special Designs

Contact Temet USA, Inc.

# Design Details

**BASIS OF DESIGN** Static Loading standard, dynamic loading optional. For dynamic loading, total impulse or triangular impulse or total duration must be specified.

**THRESHOLDS** For maximum efficiency in distributing blast loads from door plate to door frame, most higher pressure blast doors utilize a four sided or bulkhead style frame with a step over threshold. It is sometimes necessary, however, to have a level floor through the door, with threshold flush with the finished floor. Temet can supply this type of frame for SO-1 doors.

**RESCUE** All doors are furnished with latches and hinges that can be dismounted from the inside to remove the doorplate even if it is deformed after a blast that exceeds the design overpressure. Single doors can also be removed from the outside unless otherwise specified.

**LATCHES** Latch handles or wheels engage latch blocks which ready the door to withstand blast and rebound forces. Latching does not lock the door for security purposes unless an optional latch lock is ordered. Double doors can be latched only from inside. Single doors may be ordered with latches operable from inside or both sides.

**HINGE BEARINGS** Maintenance free slide bearings are standard on all SO-1 doors and available as an option on SO-3 doors. Standard SO-3 hinges have roller bearing.

**USAGE FREQUENCY** Blast doors are normally not high usage doors. In high traffic areas they are usually left open and closed only during exercises or when a blast is expected. Doors for equipment are normally kept closed except when equipment is being moved. If high usage cannot be avoided, special high usage hardware should be ordered. Low usage doors are those not in daily use. High usage doors are operated several times each day.

**LOCKING** To prevent a latched door from being opened mechanical locks or electrical deadbolts, operable from one or both sides, can be provided. These can be separate or operate by locking the latching mechanism. Position indicators and interlock systems are also available.

**GASKETS** Gaskets are not normally used on blast doors. If gas protection is required separate gastight doors are usually provided. Neoprene gaskets can be provided on all doors, however, if required.

**CHECK LIST — WHEN ORDERING STATE:**

| | |
|---|---|
| Size | English or Metric |
| Pressure/Rebound | Model number or specific requirement |
| Design Basis | Static or Dynamic loading |
| Frame Style | Surface Mount or Recessed doorplate (SO-1 double only) |
| Threshold | Raised or Flush (SO-1 doors only) |
| Hinges/Latches | Demountable from one or both sides (single doors only) |
| Latching Side | Inside only or both sides (single doors only) |
| Hinge Bearings | Roller Bearings or maintenance free Slide Bearings (SO-3 doors only) |
| Usage | Low or High |
| Locking | Mechanical or Electric, with or without interlock, position indicators, if required |
| Gaskets | If required |

**ARCHITECTURAL DRAWINGS** A full set are supplied with each catalog or brochure. Call Temet USA for additional copies.

**FRAGMENT PROTECTION** Structural steel door plates are designed to resist blast pressures, not small high velocity missiles or fragments. Although they do provide fragment resistance equivalent to reinforced concrete 6 to 12 times as thick against nearby shells and bombs, doors are normally protected from missiles/fragments by reinforced concrete enclosures. This is usually simpler and more cost effective than thicker steel or armor plate.

**POWER ASSISTED DOOR OPENERS/CLOSERS** Power assist is available but not generally recommended. All doors are designed to be latched/unlatched and closed/opened by an average size man within one minute. Power assist does not operate latches or locks.

# Specifications

Blast doors shall be constructed of structural steel and be designed for installation in the reinforced concrete blast wall of the structure. Door plate shall be solid steel mounted (on the outside surface of) (recessed in) the frame. Frame shall be (raised) (flush) threshold type. The door and frame shall be delivered and installed as a single unit. Hinges shall have (maintenance free slide bearings) (roller bearings).

Door latching mechanisms shall be operable from (one) (both) sides of the door and when closed shall tighten the door plate against the frame so that the maximum clearance between them is not greater than 5/64 inch. The maximum time required to open or close the door shall not exceed one minute. The latches and hinges shall be designed such that they can be dismounted from (the inside) (either side) of the door to enable removal of the door plate even if it has been permanently deformed.

The door and load bearing structures of its frame shall be designed to withstand, without losing its ability to function, (a static overpressure of) (a peak pressure and total impulse of) (          ) using 1.0 as the safety factor in relation to the yield point of the material.

The door shall be designed for a rebound force of (          ) percent of the blast overpressure using a safety factor of 1.3 relative to the material yield point for the components holding the door plate, and 1.0 for the rest of the structure.

The door shall be designed to withstand the stresses caused by ground shocks having a rapid change in velocity of (3.00) (2.95) ft. per second in the horizontal and (3.00) (3.94) ft. per second in the vertical direction and accelerations of (20) (30)g horizontal and (20) (40)g vertical.*

The door and its mechanisms shall operate properly within an ambient temperature range of -4°F to +122°F and remain undamaged within an ambient temperature range of -22°F to +176°F.**

US manufactured doors use materials and are fabricated in accordance with the latest editions of the following standards:

| | |
|---|---|
| Materials | ASTM Standards |
| Design and Fabrication | AISC Manual of Steel Construction |
| Welding | ANSI/AWS D 1.1 |
| Quality Control | Based on our ASME quality control system for pressure vessels. |

*Items in parenthesis, from left to right, refer to Model SO-1 & SO-3 doors, respectively.
**For temperatures beyond these ranges contact Temet USA.

**Temet USA, Inc.**

**737 Walker Road, P.O. Box 439, Great Falls, VA 22066, (703) 759-6000, Telex: 90-1932**

# PV-BLAST VALVES

**TYPE PV-60-200**

Temet USA Inc.

The PV-60-200 Series blast valves incorporate four major improvements

## Wider Pressure Range

— 160psi unrestricted long duration, 290psi to 18ms triangular impulse duration and 870psi to 1.2ms triangular impulse duration with total 4ms positive phase duration.

## Lower Pass Through Impulse

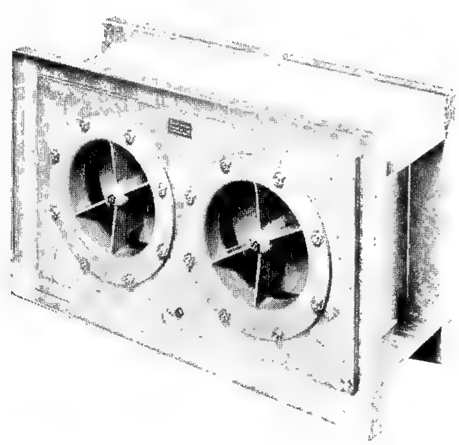
— so low, over the entire pressure range, that no expansion chamber is required behind the valves (inside the blast wall) and lightweight components such as filters and ducts can be installed as close as two feet from the valves. Blast tested Temet filters can be bolted directly on the valves.

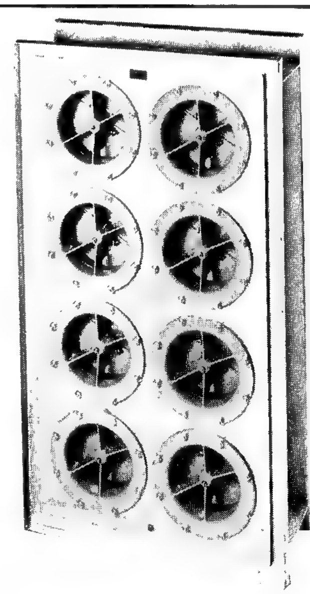
## Modular Design

— up to 10 valves per standard module with special modules to a maximum of 50 valves. Multiple modules, supported by structural steel columns, can be used to make walls of valves.

## Flush Mount Casings

are now standard so no valve parts extend beyond the surface of the blast wall. For "Fast Track" projects, casings can be supplied quickly for the concrete pour and valves delivered and installed later.





## Air Flow Capacity

910SCFM at the recommended maximum 2.0 inch W. G. Pressure Drop, 690SCFM at the recommended nominal 1.2 inch W. G. Pressure Drop.

## Quality Control

based on our ASME type Quality Control System extended to incorporate NATO and Norwegian Military standards and Finnish Civil Defense standards. Temet valves meet and exceed Swiss Civil Defense standards.

# Design Information

**AIR FLOW.** Select valve capacity from the air flow chart below. Recommended design pressure drop is 300Pa (1.2 inches WG). Recommended maximum pressure drop is 500Pa (2.0 inches WG). Noise generation can begin to occur in some cases when pressure drop exceeds 1.2 inches.

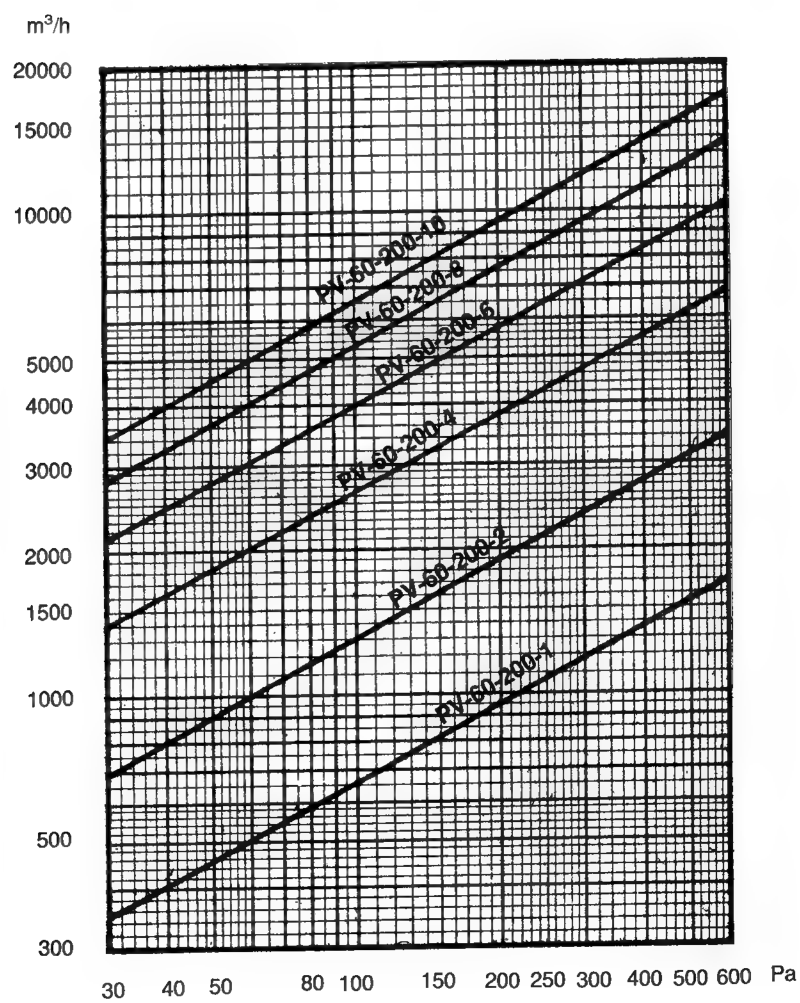
**CONVERSION FACTORS**

CFM x 1.7 = $M^3/H$
inches WG x 249 = Pa

**BLAST ATTENUATION.** Due to a change in basic design the portion of the blast wave that is able to pass through the valve before it closes is so small that standard ventilation equipment will not be damaged providing the following requirements are met.

Equipment must be at least 2 feet away from the valve in any direction.

The cross sectional area of the space 2 feet directly behind the valve must be no less than the area of the blast valve wall.




**Air Flows at Standard Conditions (760mm Hg, 20 degrees C)**

# Specifications

Blast valves shall consist of an aluminum alloy pressure disk mounted on a stainless steel spindle mechanism within a nodular cast iron valve body. Valves shall close in one direction in response to the positive phase of the blast wave and in the opposite direction in response to the negative phase. Valves shall be designed for mounting in factory fabricated casings.

Valves and casings shall be designed to withstand reflected peak over pressures of 870psi up to 4ms and 160psi for 30ms or longer. The pass through impulse leaving the valve shall not exceed 0.006psi-seconds, as measured in a 500mm impulse tube, regardless of inlet blast pressure. Closing time shall not exceed 1.1ms under a 160psi long duration blast load. Valves shall remain fully operable after testing at these loadings. Reports from an independent testing laboratory confirming this performance shall be furnished by the manufacturer on request.

Valve casings shall be structural steel designed for flush mounting in reinforced concrete walls. No valve parts shall extend outside the casing.

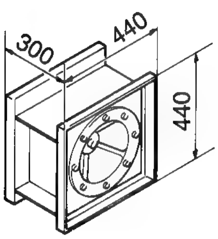
Valves shall withstand a mechanical shock equivalent to a sudden change in velocity of 1.5 meters per second and the stresses of a dropping test with an acceleration of 80g.

Valves shall have an operating temperature range of −4 degress F to +176 degrees F with standard surface treatment and up to +302 degrees F with optional high temperature surface treatment.

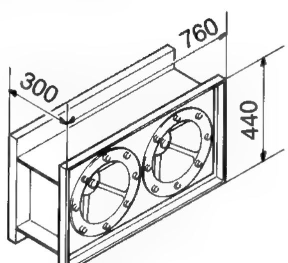
Valve shall be completely corrosion resistant. All components of the spindle mechanism shall be stainless steel. Structural steel casing shall be hot dip galvanized. Other parts susceptible to corrosion shall be coated with a corrosion resistant epoxy powder.

# Layout Dimensions

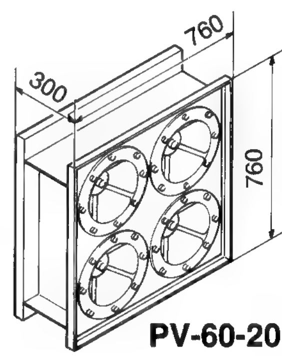
(In millimeters—25.4mm = 1 inch)



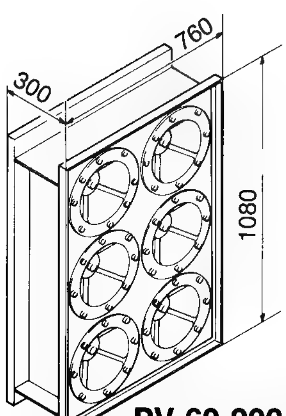

PV-60-200-1



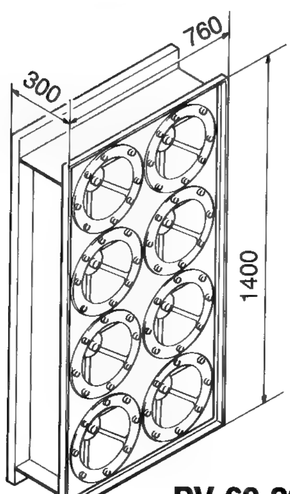

PV-60-200-2



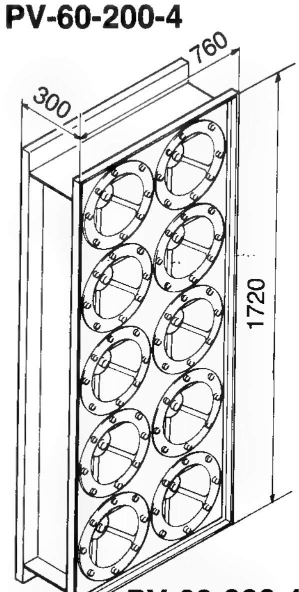

PV-60-200-4




PV-60-200-6

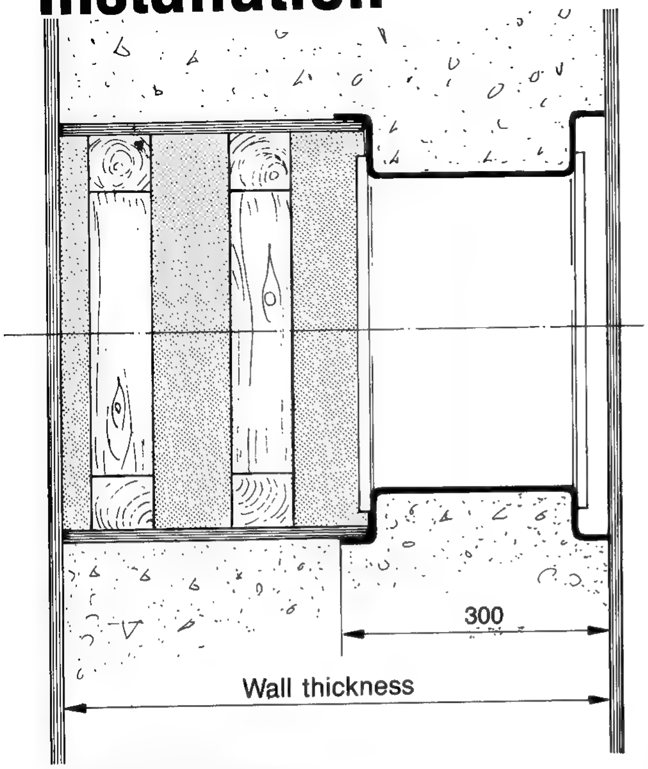


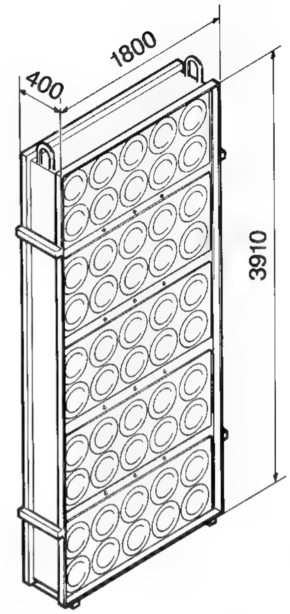

PV-60-200-8




PV-60-200-10

# Installation




## STANDARD MODULES (1 to 20 valves)

The valve casings are placed in the wall prior to pouring of concrete. The forms are placed directly on the outside edges of the casing as shown on the right side of the drawing above. For walls thicker than 300mm (12 inches) the remainder of the air channel must be blocked out as shown on the left side of the drawing.

If necessary, the casing may be installed without the valves which can be bolted in place at a later time.

Valve casings may be mounted either horizontally or vertically.

## SPECIAL MODULES (up to 50 valves)

Special modules of up to 50 valves can be supplied in order to minimize blast wall area. Multiple 50 valve modules, supported by structural steel columns can be used to make walls of valves.

If standard installation arrangements do not appear to suit your project, contact Temet USA for custom designed mounting arrangements.

Weight is approximately 100 pounds per valve including casing.

Blast tested air filters which bolt directly to valves are available for intake air valves.


**Temet USA, Inc.**

737 Walker Road, P.O. Box 439, Great Falls, VA 22066, (703) 759-6000, Telex: 90-1932

# S H E L T E R S

# Concrete Systems, Inc.

***Presents***

# Precast Concrete Buildings

00924

# CSI

# PRECAST CONCRETE BUILDINGS

## Help You Meet The Tightened Constraints Resulting From The Graham-Rudman Act

- Reduced Project Cost
- Standardized Engineering
- Easy Procurement
- Streamlined Construction
- Expandable Usage
- Zero Maintenance

# CSI

## PRECAST CONCRETE BUILDINGS

### Help You Beat The High Cost Of On-Site Construction

- Reduced Project Cost
- Standardized Engineering
- Easy Procurement
- Streamlined Construction
- Expandable Usage
- Zero Maintenance

# OFF-THE-SHELF DESIGN

**SIZES:**

Up to 1,400 Square Feet

**Heights:**

8 to 12 Feet Clear Ceiling Height

**Configurations:**

Any Shape That Can Be Accomplished Using Standard Building Practices

**Finishes:**

Exposed Aggregate, Mat Finishes, Brick Veneer, Clapboard, Texture 1-11

**Accessories:**

To Any Customer Specifications

**Other:**

Unlimited Flexibility Is Built Into Our System

# STREAMLINED CONSTRUCTION

## Buildings Are Supplied:

**Complete** (Keys in Door)
**Delivered** (Throughout Continental U.S.A.)
**Set-in-Place** (Ready for Occupancy)

## Off-the-Shelf Designs Mean:

**Immediate Delivery**
**Immediate Occupancy**

## Owner's Or Contractor's Responsibilities Are For:

**Footing Preparation** (Available By CSI If Requested)
(Requiring Leveled Crushed Stone)
**Hook Up of Utilities**
**Building Permits**

## Construction Time:

**Ready for Use Within 24 Hours of Delivery**

# STANDARD SPECIFICATIONS

- Cost Competitive
- Professionally Designed
- Easily Transportable
- Same Day Occupancy
- Expandable
- Many Architectural Finishes
- Maintenance Free
- Factory Engineered To:
  - Seismic (Zone I)
  - 125 MPH Wind Load (May Be Increased)
  - 60 PSF Roof Live Load (May Be Increased)
  - 100 PSF Floor Live Load (May Be Increased)
  - Fire Resistant (2 Hours)
  - Bullet Resistant (ANSI/UL Threat Levels I-IV/May Be Increased)
  - Attack Resistant (2 Minutes DOD AA&E/May Be Increased to 30 Minutes)

# CSI

## PRECAST CONCRETE

(Fully Assembled Transportable Building)

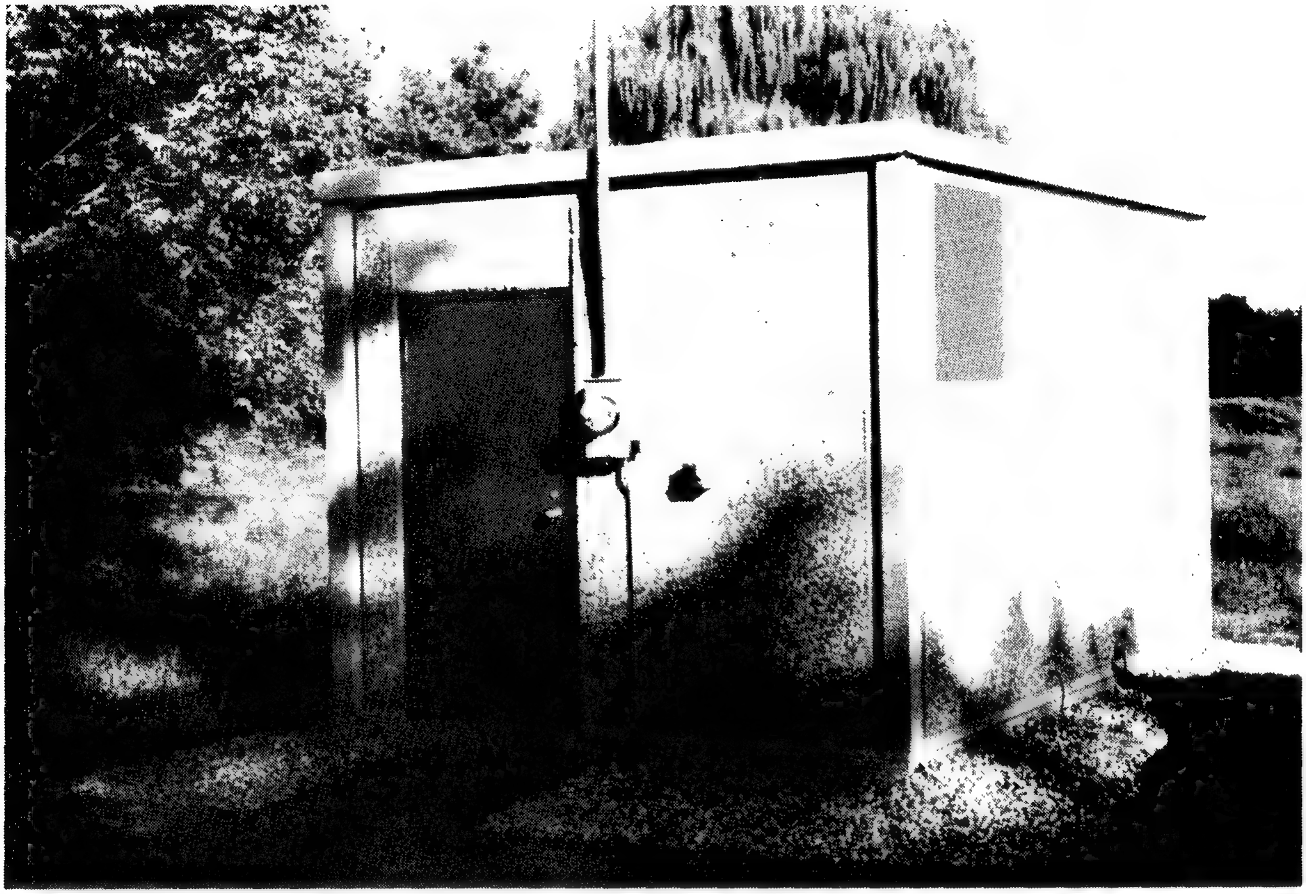
### UNIQUE FEATURES:

- Inventoried in Standard Sizes (Available in Custom Sizes)
- Shipped and Installed Fully Equipped

### UNIQUE BENEFITS:

- Requires Minimum or No Site Preparation
- Can Be Easily Relocated As Required
- Can Be Pre-Fabricated to Project Requirements

# PRECAST CONCRETE EQUIPMENT HUT (PCH)-1



This environmentally controlled building has been developed by New England Telephone and AT&T consumer products as a fibre optics/SLC-96 building that will house up to 15 racks of equipment. It offers the following advantages:

- Professionally designed and engineered
- Requires crushed stone foundation only
- Easily transported
- Vandal proof
- Bullet proof
- Water proof
- Fire proof
- Easy zoning and code approval
- Architecturally pleasant finish
- Maintenance free

**Manufactured by:**
**Concrete Systems, Inc.**
Commercial Avenue
Hudson, New Hampshire 03051
Tel. (603) 889-4163

**Offered by:**
**AT&T Consumer Products**

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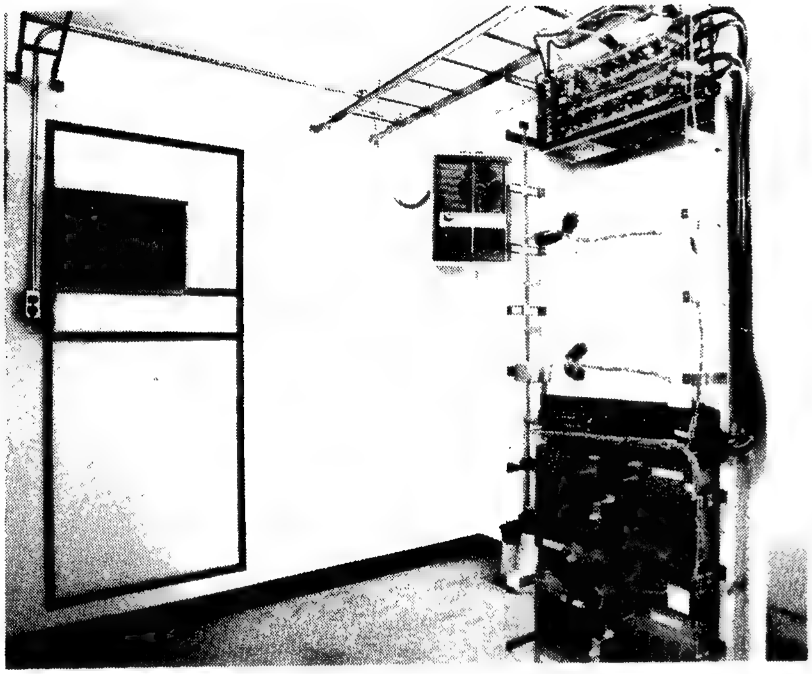
# PRECAST CONCRETE EQUIPMENT HUT



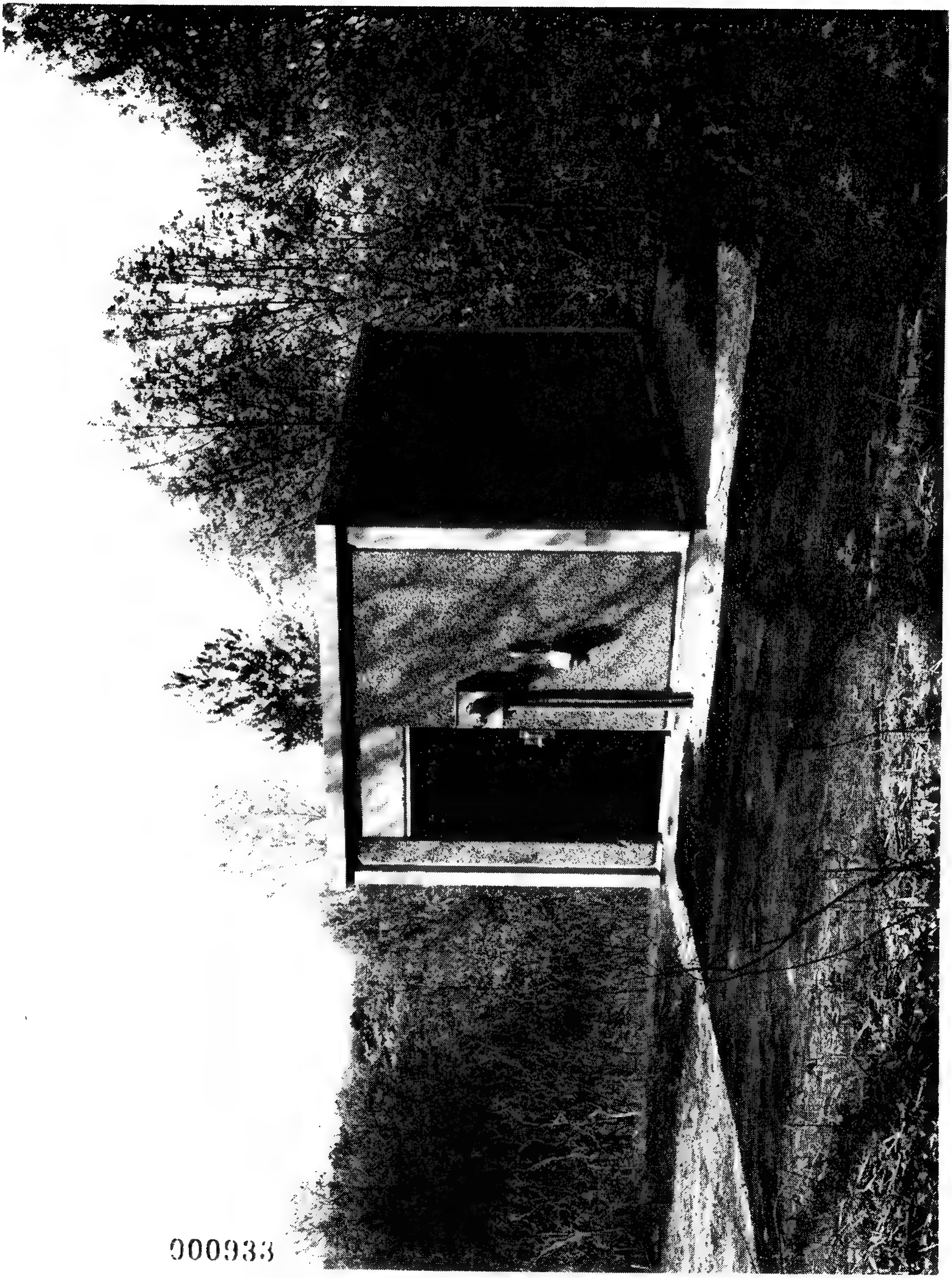
## Precast Concrete Hut

| | |
|---|---|
| Size: | The interior measures 13 feet, 6 inches long by 9 feet wide and 8 feet in height. |
| Capacity: | The Precast Concrete Hut can accomodate 15 fibre-optic/SLC-96 racks. |
| Security: | The Precast Concrete Hut is well secured. "Silent" Alarm (alarms sound only at the central office, not at the enclosure site) provides protection against unauthorized entry. |
| Primary Power: | The power source is commercial 117 VAC, 60 Hz. |
| Back Up Power: | Each SLC-96 system has a string of 48 VDC batteries that can provide operation for a minimum of eight hours during commercial power failure. Additionally, each building has an external plug and manual transfer switch for a portable generator. |
| Climate Control: | An electronic controller regulates the huts interior temperature and humidity. The controller also operates an air conditioner and electric ceiling hung heater. |

**Manufactured by:**
**Concrete Systems, Inc.**
Commercial Avenue
Hudson, New Hampshire 03051
Tel. (603) 889-4163

000932

**Offered by:**
**AT&T Consumer Products**



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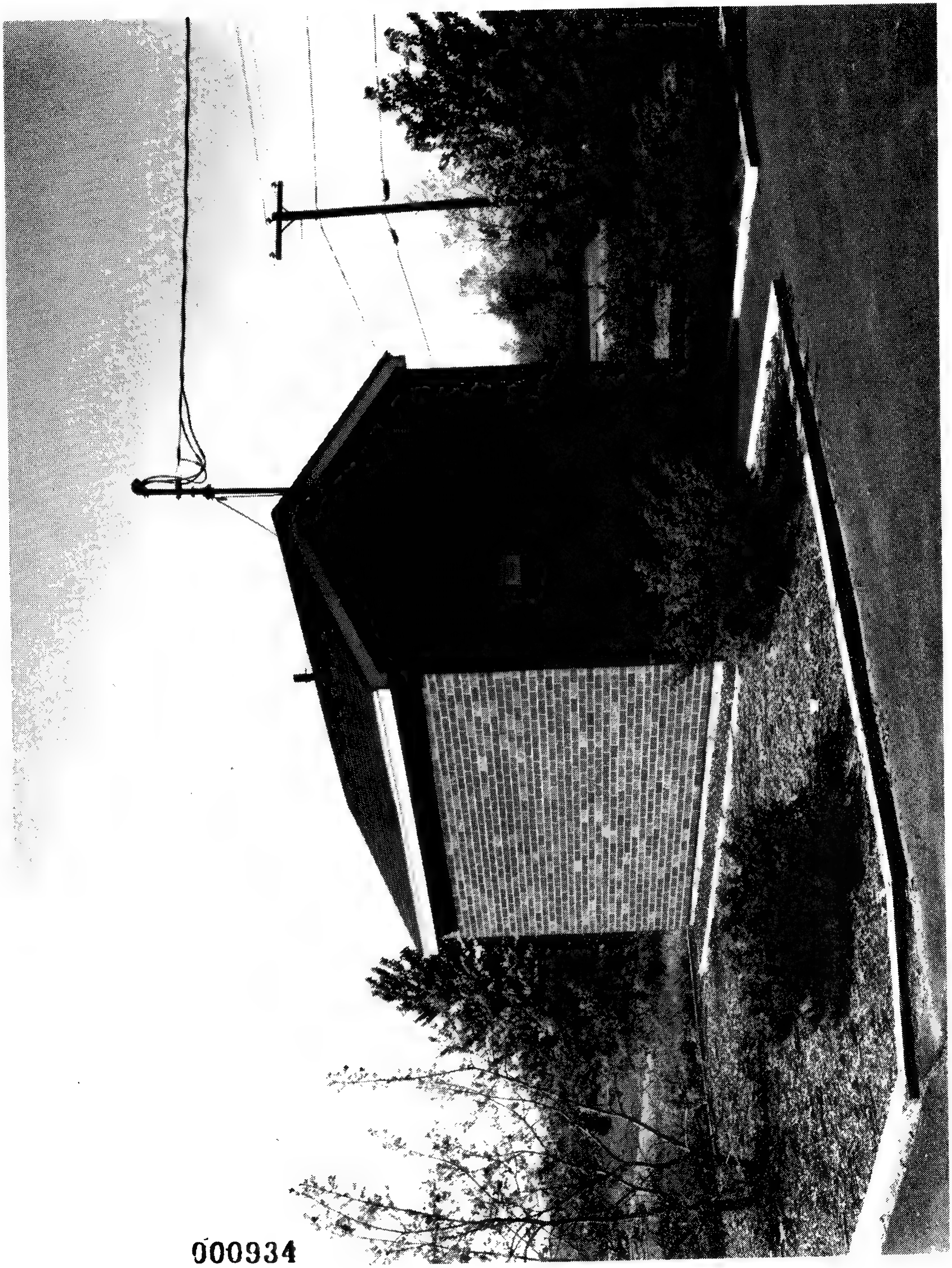

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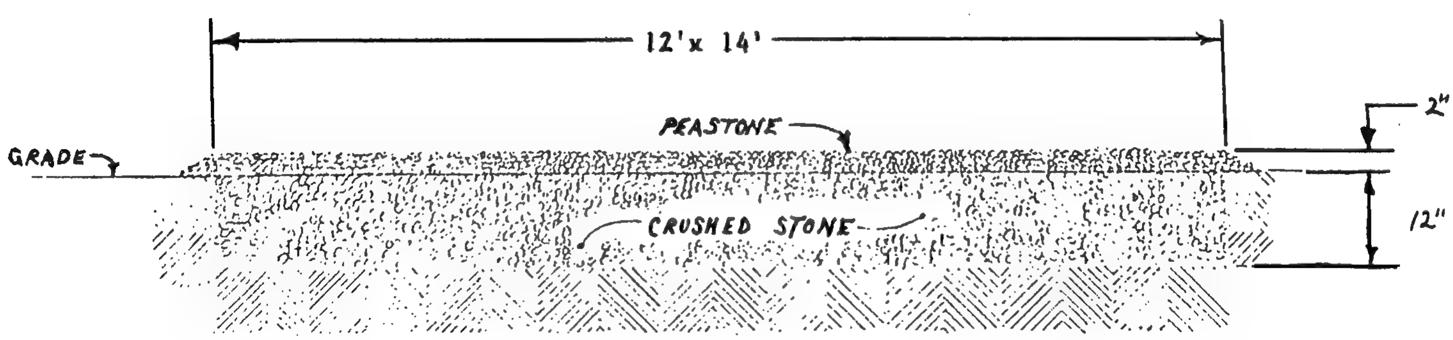
CONCRETE SYSTEMS INC.

SITE PREPARATION REQUIREMENTS SHEET
FOR A 10' x 12' x 7'6" PRECAST CONCRETE BUILDING

Proper ground conditions must be of a self-draining and self-leveling material such as gravel, crushed stone, or sand that is compacted and perfectly level. Our recommendation is 12" of crushed stone on a solid base and that the final 2" thick surface of pea stone be a few inches higher than grade for surface drainage..





| | | | | |
|---|---|---|---|---|
| 1179 A Ponoella Rd., | North Fort Myers, | Florida | 33903 | 813-574-6790 |
| Commercial Avenue, | Hudson, | New Hampshire | 03051 | 603-889-4163 |
| 400K Lake Front Dr., | Raleigh, | North Carolina | 27612 | 919-787-8093 |

# CSI

## PRECAST CONCRETE

(Site Erect - Panel Building)

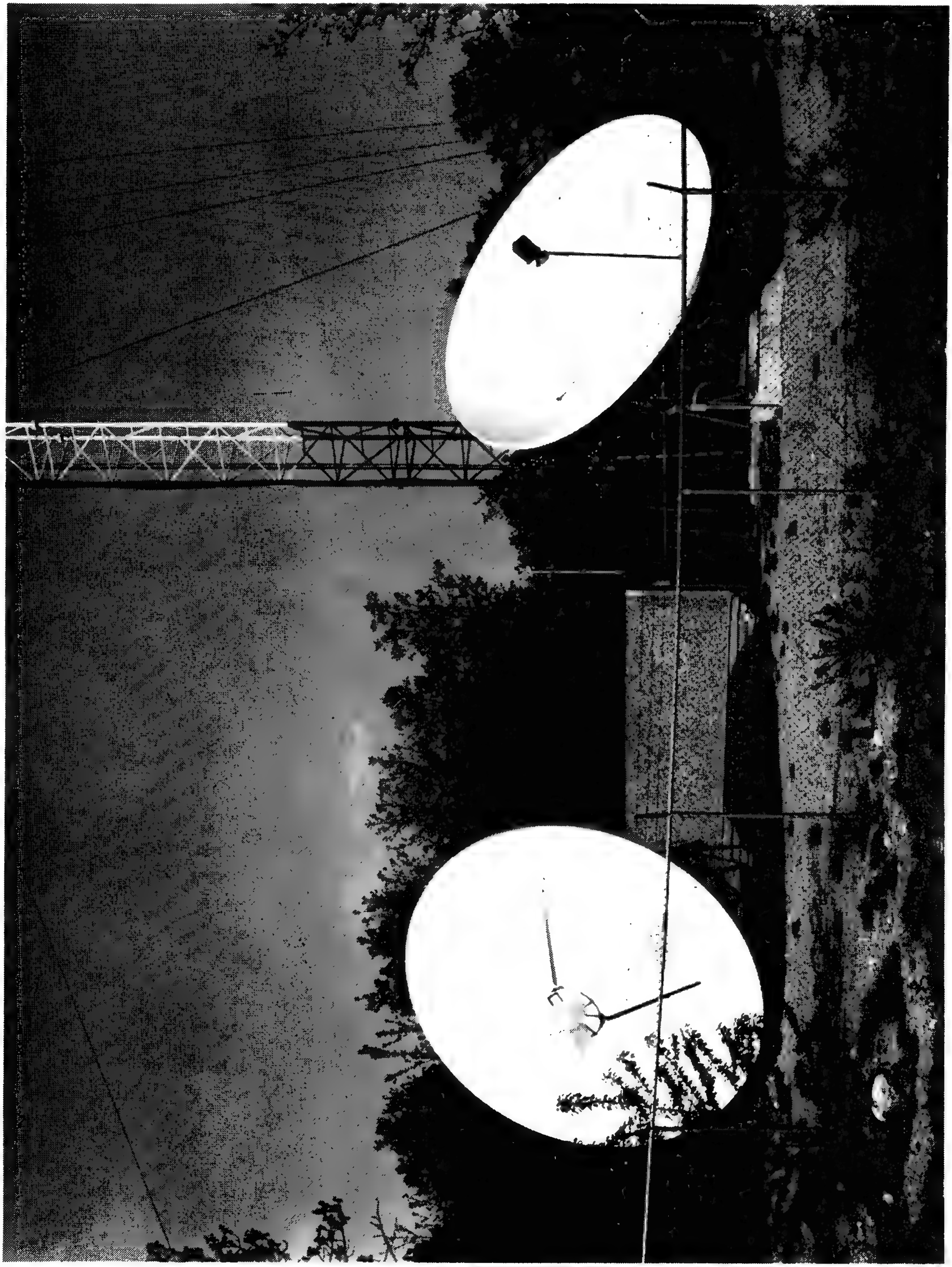
**UNIQUE FEATURES:**

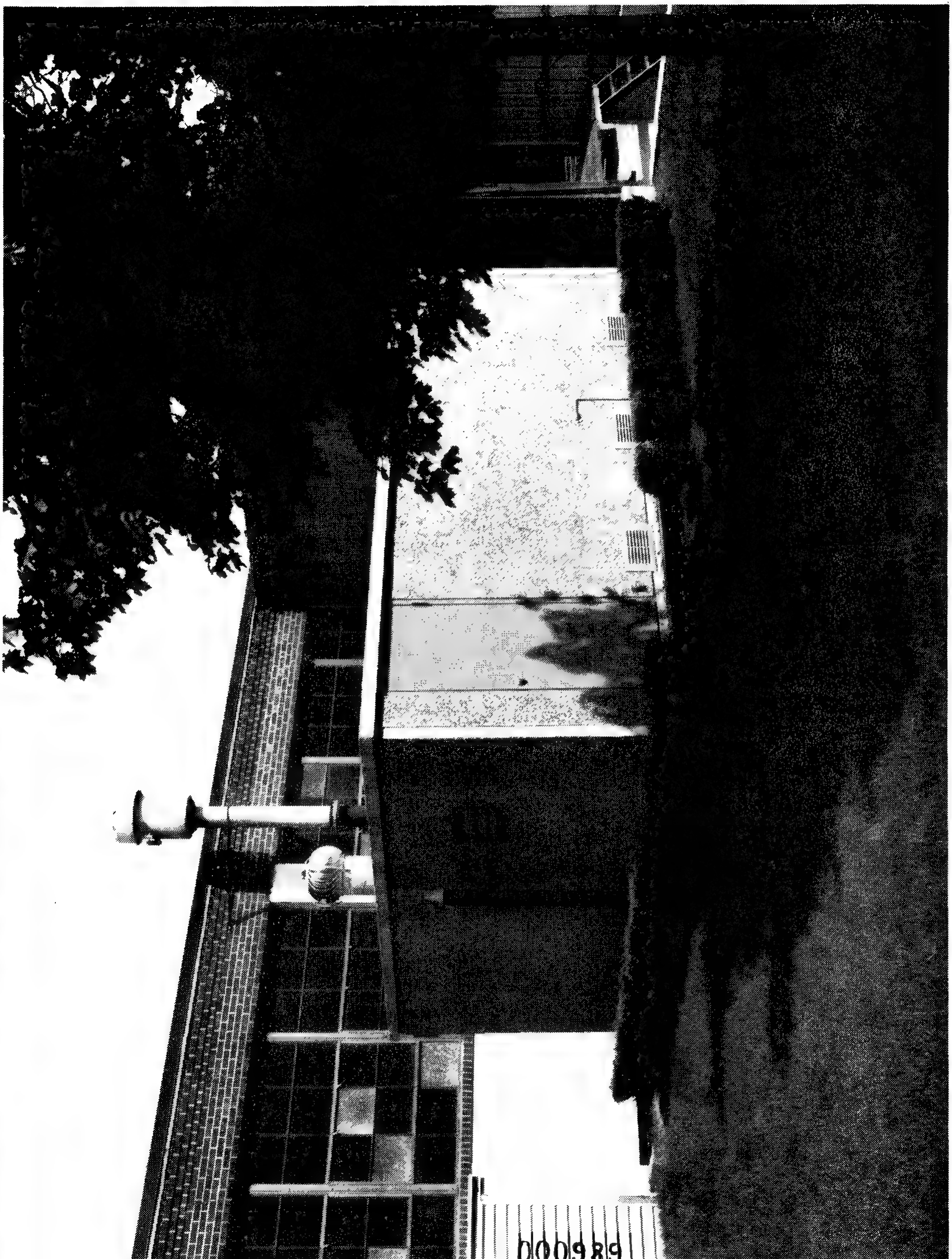
- Can Be Readily Fabricated to Project Requirements
- Facilitates Complex Configurations & Floorplans

**UNIQUE BENEFITS:**

- Can Install Over Existing Equipment Without Interruption
- Can Be Easily Shipped and Installed at Remote Sites with Lightweight Equipment

000937





000989

# CSI

## PRECAST CONCRETE

(Modular Communication Building)
(Mod Comm)

**UNIQUE FEATURES:**

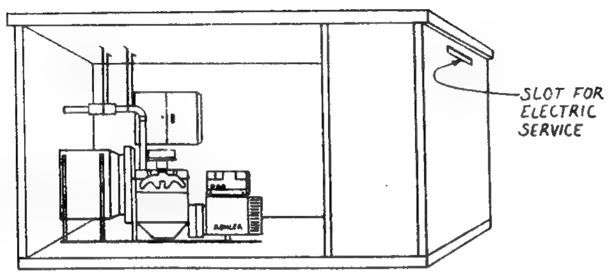
- A Wide Range of Finished Floor Area From 140 Square Feet to 1,400 Square Feet (1-10 Modules)
- Modules Are Precast As A Monolithic Unit Including Floor, Walls & Roof
- Designed to Be Easily Transported and Site Erected

**UNIQUE BENEFITS:**

- Lower In-Place Cost Than Conventional Buildings
- Superior Ballistic & Attack Resistance in Comparison to Other Types of Construction
- Requires Only Minimum Site Preparation
- Lasts Longer Than Other Types of Construction
- Simplifies, Shortens & Improves The Quality of Construction Projects

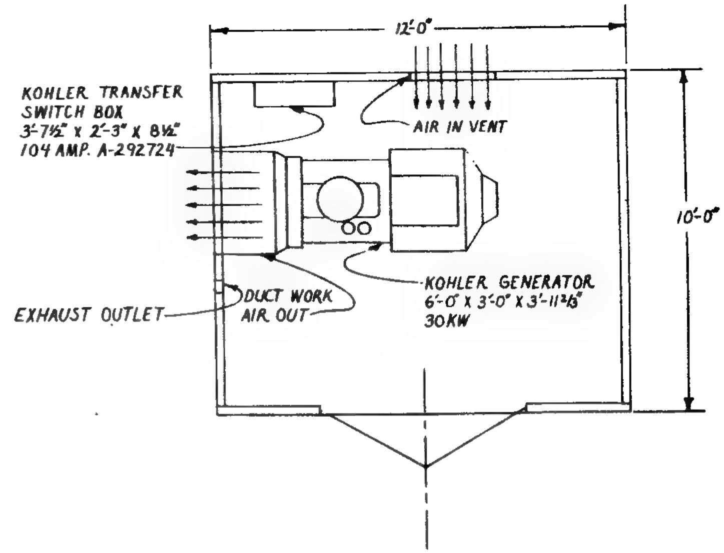
# AVAILABLE OPTIONS

- Insulation (R-7 Through R-21)
- Drywall and Painting
- Paneling
- Floor Tile
- Electrical Wiring
- Halon Systems
- Louvers and Halon Shutters
- Dehumidifiers
- Environmental Controllers
- Air Conditioning
- Specialized Exterior Doors Including Armor Plate
- Interior Doors & Partitions
- Interior and Exterior Lighting
- Generator's Installed or Exterior Generator Plugs Supplied
- Interior Grounding Grid and/or Bus Bars
- Cable Entrances Installed
- Cable Tray or Ladder Installed
- Sinks and Toilets Installed
- Floor Drains and/or Scuppers
- Cast in Inserts for Equipment Mounting
- Special Architectural Finishes




FRONT LEFT PANEL AND DOUBLE DOORS
HAVE BEEN REMOVED FOR VIEWING

EXTERIOR FINISH~BROWN OR GRAY AGGREGATE




PLAN VIEW 3/8"=1'-0"

## GENERAL SPECIFICATIONS

DIMENSIONS
INTERIOR 9'-6" x 11'-6" x 6'-10"
EXTERIOR 10'-0" x 12'-0" x 7'-6"

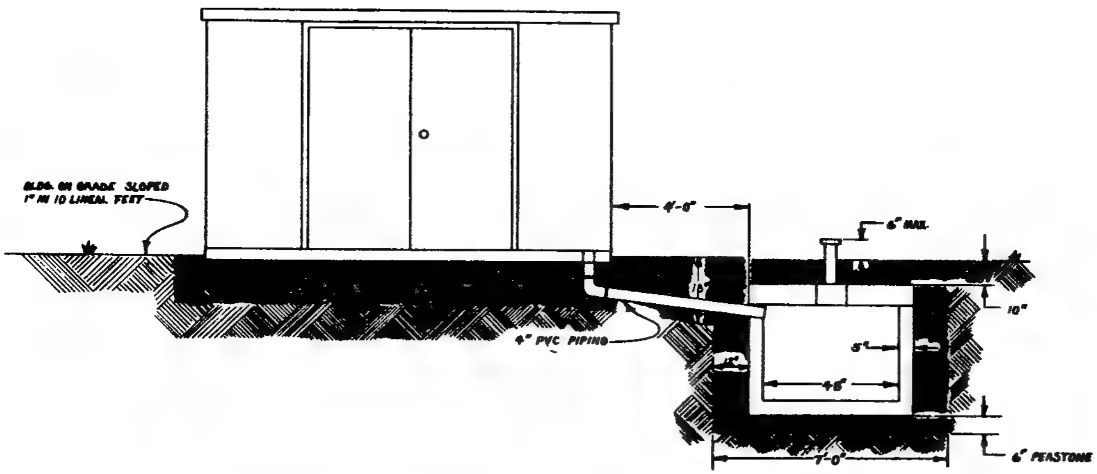
4,000 PSI REINFORCED CONCRETE

ROOF LOAD CAPABILITIES
40 PSF LIVE LOAD

FIRE RESISTANCE RATING - 1½ HRS.

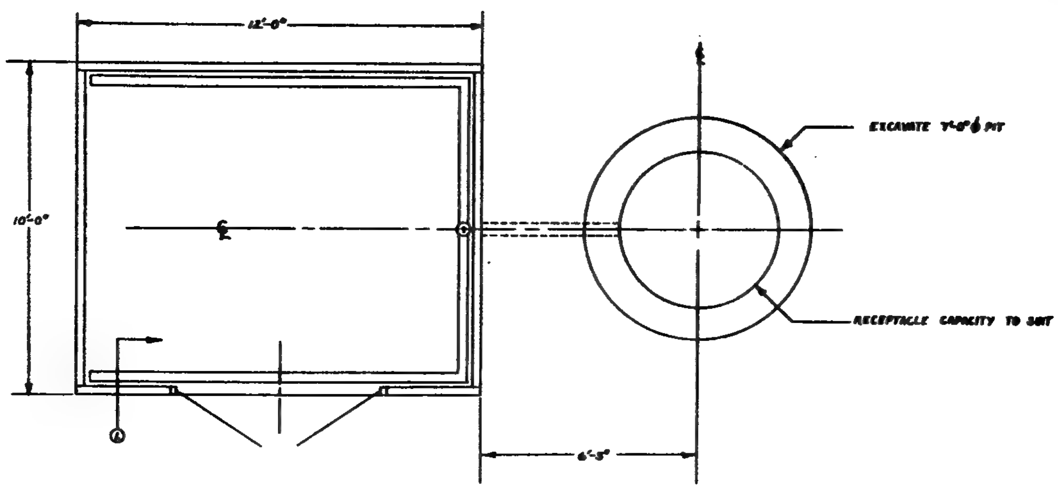
WIND LOADING
27 PSF OR 130 MPH

| | | |
|---|---|---|
| CONCRETE SYSTEMS INC. | | |
| SCALE | APPROVED BY | DRAWN BY BAC |
| DATE 5-8-81 | | REVISED |
| WHITMAN & HOWARD WELLESLEY, MA. | | |
| LONGCHAMPS & SON MANCHESTER, ME. | | DRAWING NUMBER B-0011 |

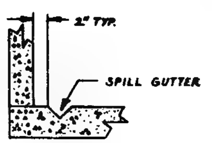



*All PVC piping supplied & installed by others

*Manhole excavation & installation by others

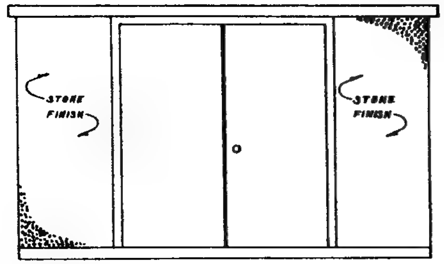



PLAN VIEW

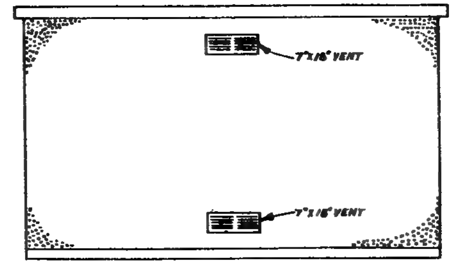



1 SPILL GUTTER DETAIL

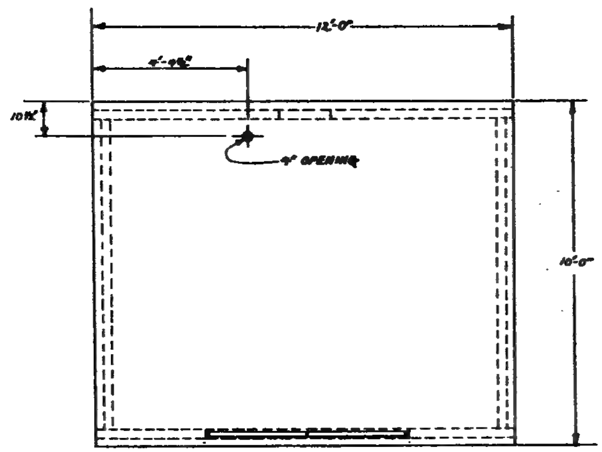
| | | |
|---|---|---|
| CONCRETE SYSTEMS INC. | | |
| SCALE 3/8" = 1'-0"<br>DATE 7-22-81 | APPROVED BY: F.I | DRAWN BY BAC |
| HADCO PRINTED CIRCUITS | | |
| CHEMICAL STORAGE FACILITY | | E-0032 |




FRONT ELEVATION




REAR ELEVATION




ROOF VIEW

## GENERAL SPECIFICATIONS

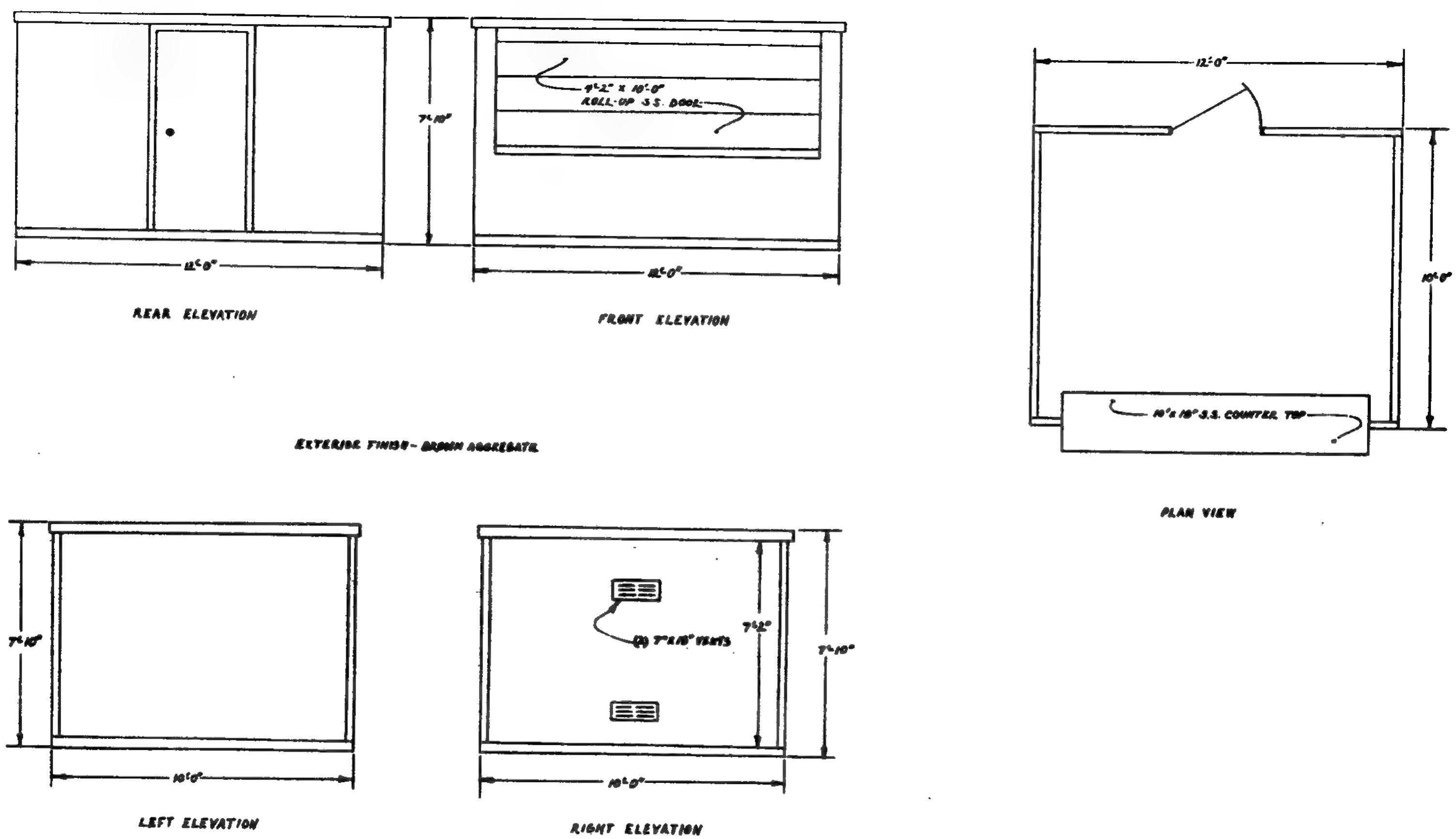
DIMENSIONS EXTERIOR – 10' x 12' x 7'-6"
INTERIOR – 9'-6" x 11'-6" x 6'-10"
REINFORCED CONCRETE – 4,000 PSI
ROOF LOAD – 40 PSF
WIND LOADING – 27 PSF

CONCRETE SYSTEMS INC.

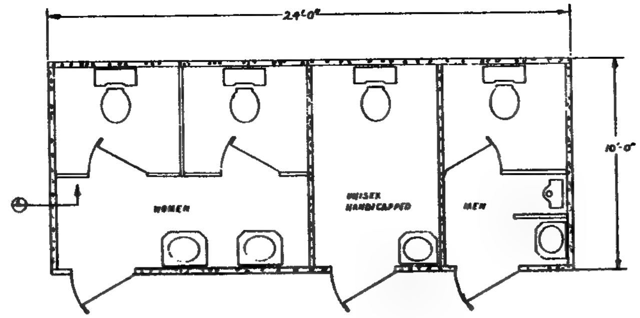
9-3-81
BAC
1/8" = 1'-0"

WHITE OAK CONSTRUCTION CO.

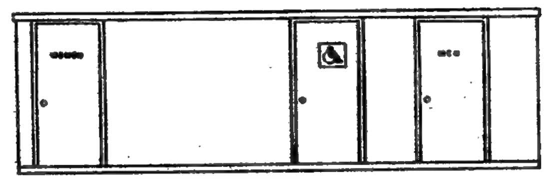
2-77402



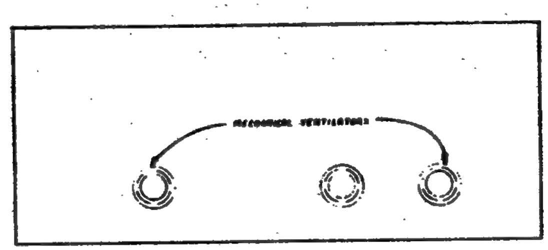

| CONCRETE SYSTEMS INC. | | |
|---|---|---|
| DATE 4-23-81 | DRAWN BY BAC | APPROVED BY |
| SCALE 3/8" : 1'-0" | REVISED | |
| CONCESSION STAND | | |
| EAST NASHUA LITTLE LEAGUE | | DRAWING NUMBER 6-0004 |



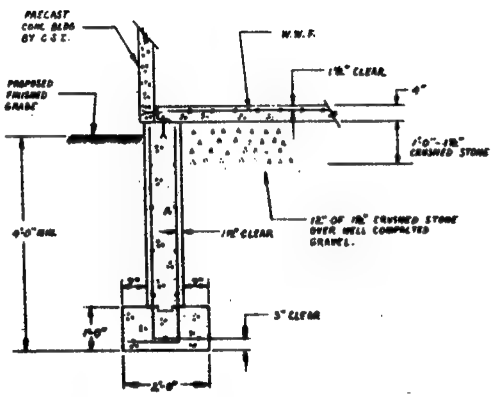

FLOOR PLAN
SCALE: 1/4" = 1'-0"



FRONT ELEVATION
SCALE: 1/4" = 1'-0"

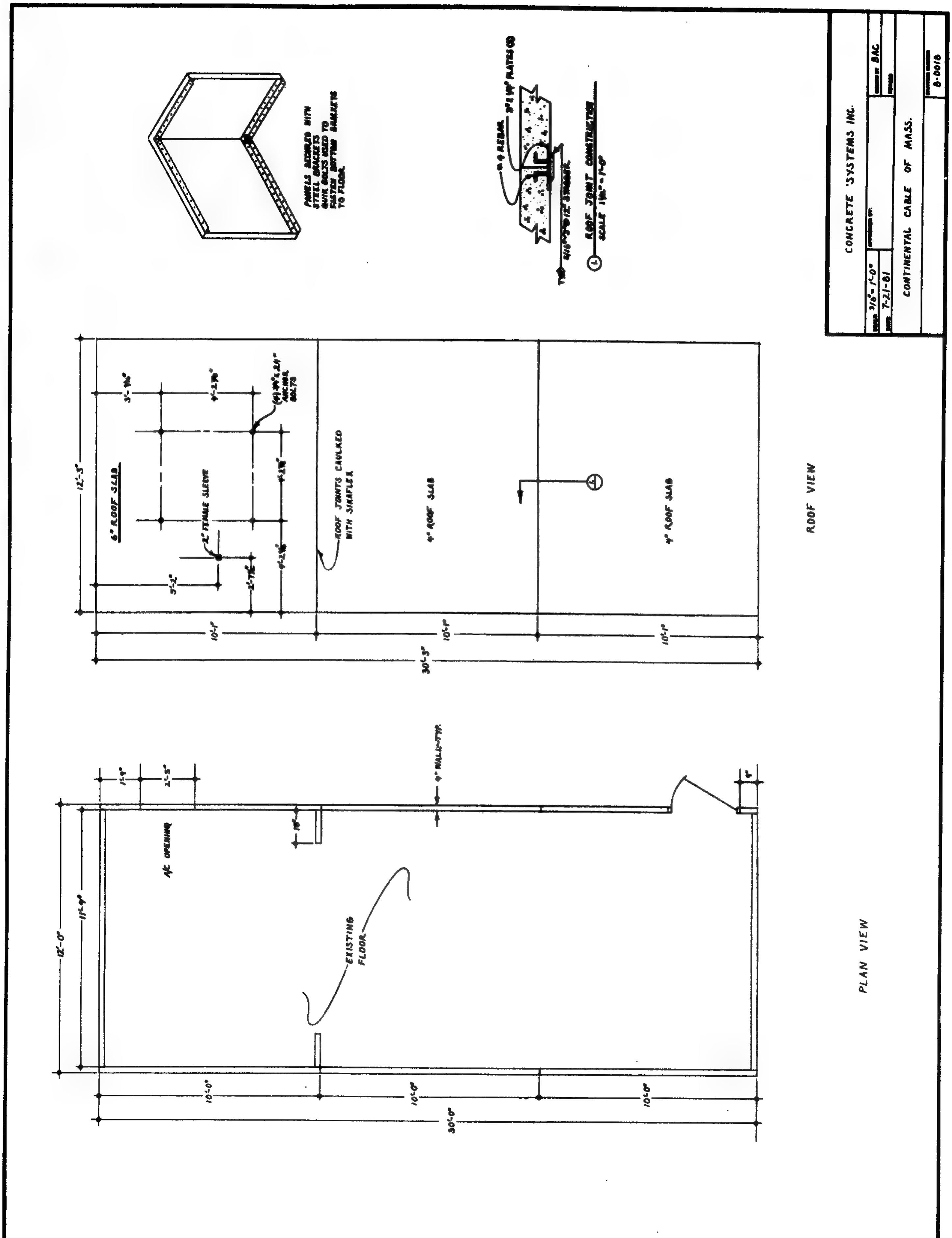



ROOF VIEW
SCALE: 1/4" = 1'-0"

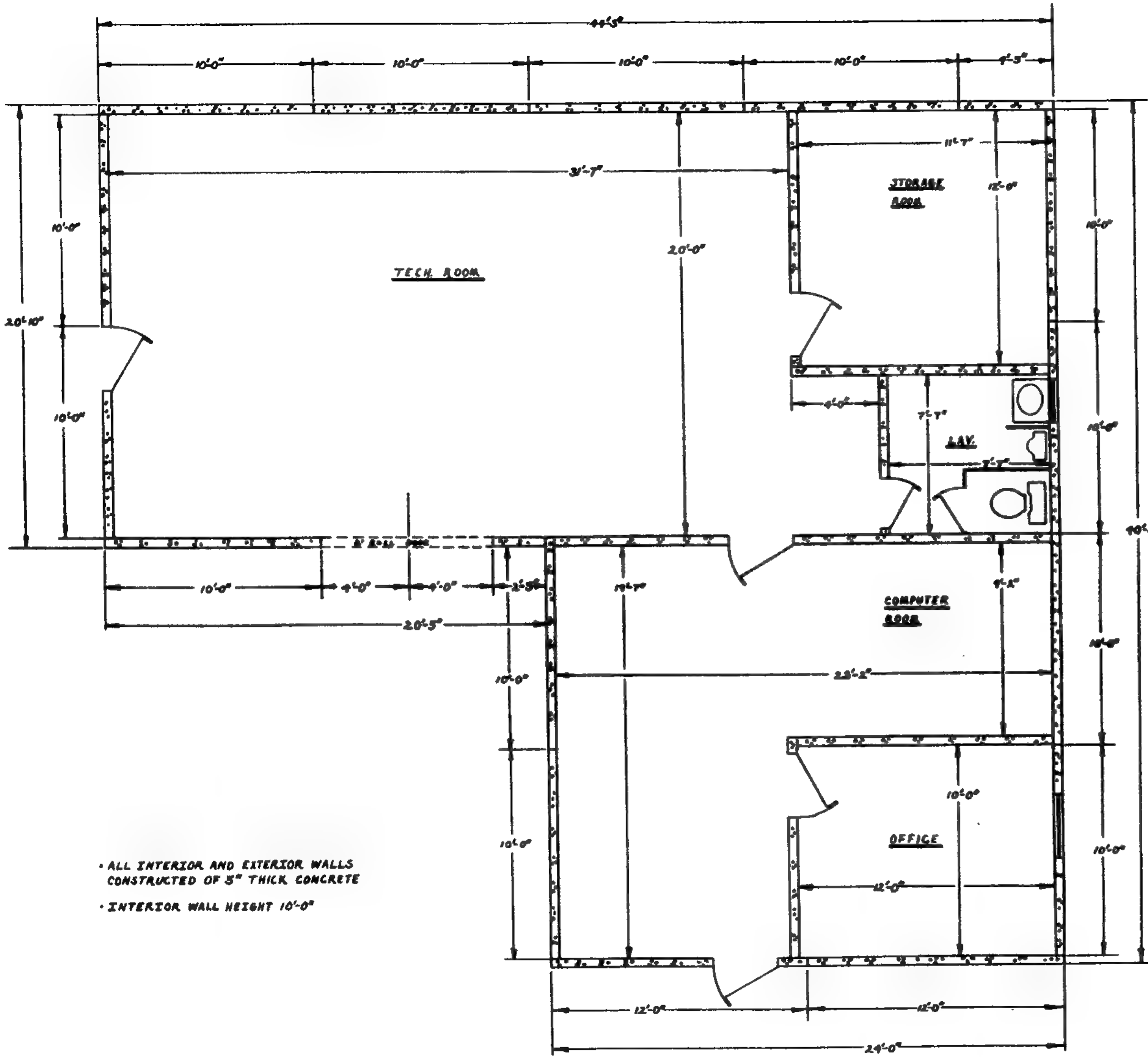



FOUNDATION DETAIL
SCALE: 1/2" = 1'-0"

| | | |
|---|---|---|
| CONCRETE SYSTEMS INC. | | |
| 7-29-81 | BAC | |
| - | | |
| COMMUNITY SERVICES - ANDOVER, MA | | |
| RESTROOM FACILITY | | R 79480 |


CONCRETE 'SYSTEMS INC.
3/16" = 1'-0"
7-21-81
BAC
CONTINENTAL CABLE OF MASS.
B-0018
PANELS SECURED WITH STEEL BRACKETS
ROOF JOINT CONSTRUCTION
SCALE 1 1/2" = 1'-0"
6" ROOF SLAB
2" FEMALE SLEEVE
ROOF JOINTS CAULKED WITH SIKAFLEX
4" ROOF SLAB
4" ROOF SLAB
12'-3"
10'-1"
10'-1"
10'-1"
30'-3"
ROOF VIEW
A/C OPENING
EXISTING FLOOR
4" WALL-TYP.
12'-0"
11'-4"
10'-0"
10'-0"
10'-0"
30'-0"
PLAN VIEW

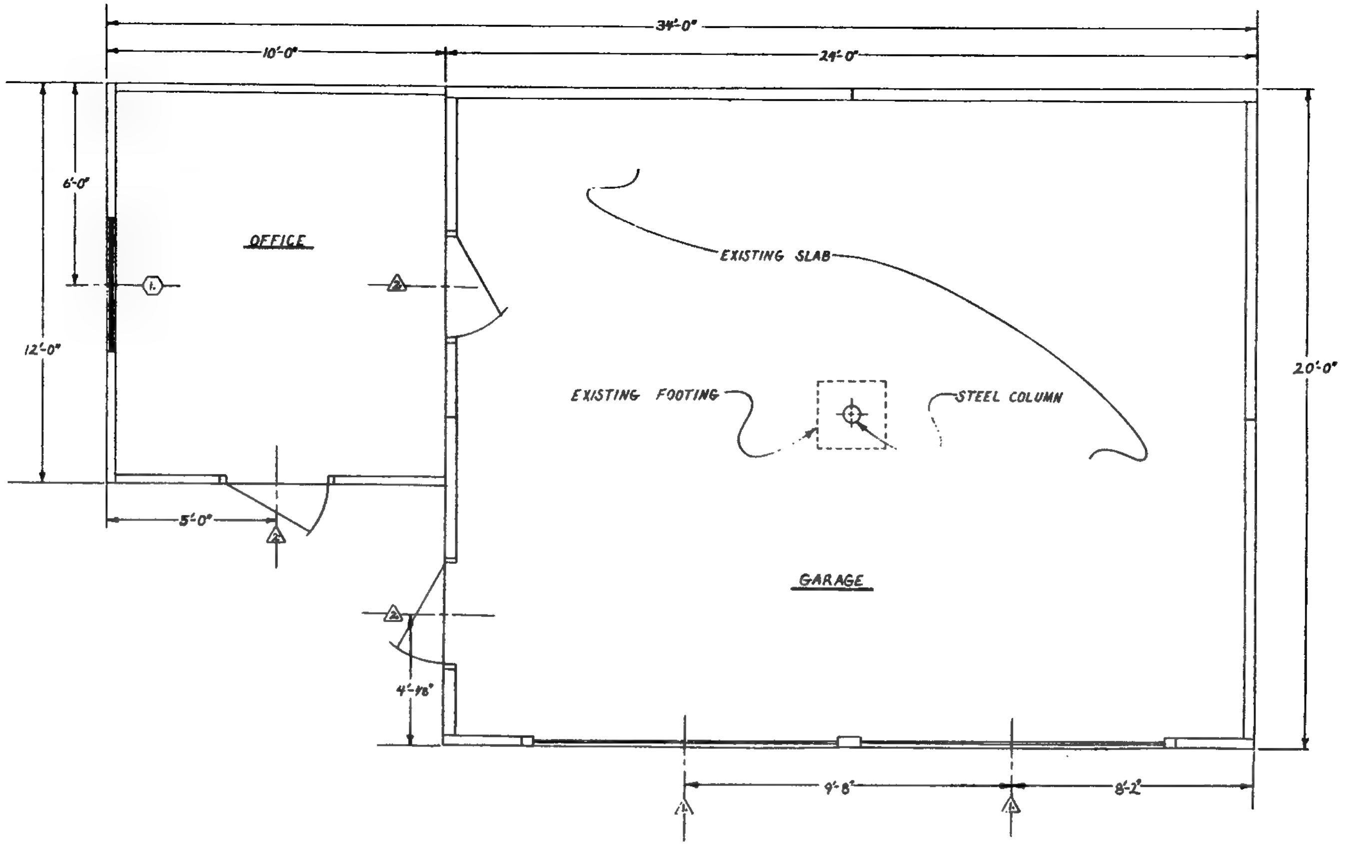
FLOOR PLAN
SCALE: 1/4" = 1'-0"




• ALL INTERIOR AND EXTERIOR WALLS CONSTRUCTED OF 3" THICK CONCRETE

• INTERIOR WALL HEIGHT 10'-0"

| | | |
|---|---|---|
| CONCRETE SYSTEMS INC. | | |
| 8-4-81 | BAC | |
| 1/4" = 1'-0" | | |
| ROLLINS CABLEVISION INC. | | |
| | | B-7309 |




| DOOR SCHEDULE | | | | |
|---|---|---|---|---|
| SYM. | SIZE | TYPE | MATERIAL | QUAN. |
| 1 | 9'-0" x 7'-0" | OVERHEAD | WOOD | 2 |
| 2 | 3'-0" x 6'-8" | STANDARD | STEEL | 3 |

| WINDOW SCHEDULE | | | | |
|---|---|---|---|---|
| SYM | SIZE | TYPE | MATERIAL | QUAN. |
| 1 | 48" x 24" | SLIDING | POLY-CARBONATE GLAZ | 1 |

GENERAL SPECIFICATIONS

| DIMENSIONS | GARAGE | OFFICE |
|---|---|---|
| INTERIOR | 23'-4" x 19'-6" x 8'-0" | 9'-3" x 11'-6" x 6'-10" |
| EXTERIOR | 24'-0" x 20'-0" x 8'-8" | 10'-0" x 12'-0" x 7'-6" |

REINFORCED CONCRETE
4000 PSI

ROOF LOADING CAPABILITIES
40 PSF LIVE LOAD

WIND LOADING
27 PSF OR 130 MPH

| CONCRETE SYSTEMS INC. | | |
|---|---|---|
| SCALE 3/8" = 1'-0" / DATE 5-15-81 | APPROVED BY | DRAWN BY BAC / REVISED |
| MOTORLAND INC. | | |
| | | DRAWING NUMBER B-0015 |

# VEHICLE BARRIERS

**REFERENCE**

# VEHICLE BARRIER INFORMATION

PREPARED BY
NAVAL SEA SYSTEMS COMMAND
AUGUST 1984

## TABLE OF CONTENTS

# ABSTRACT

## "THE APPLICATION OF AIRCRAFT ARRESTING SYSTEM TECHNOLOGY TO VEHICLE BARRICADES"

by: Kevin Mulligan
Project Manager
All American Engineering Co.

### PROBLEM

How to safely prevent unwanted vehicles from entering secure areas.

### OBJECTIVE AND SCOPE OF WORK

The referenced presentation will cover a new approach to physical barricades using technology that All American Engineering Company (AAE) has been utilizing for 25 years on runway-based aircraft arresting systems. These systems physically grab hold of runaway fighter aircraft and bring them to a safe stop within a short distance.

### CURRENT TECHNOLOGY

Most fighter aircraft are equipped with tailhooks that can pick up a steel cable lying on the runway (as on aircraft carriers). Those without tailhooks are engaged by a large nylon net on the runway. The cable or net is attached to a nylon tape which is wound onto water turbine energy absorbers mounted on each side of the runway. As the aircraft engages the system, it unwinds the nylon tape and turns the water turbine which creates the braking force necessary to stop the aircraft.

AAE has used this technology to arrest everything from small projectiles to B-52 aircraft. AAE's Model 14 water turbine system is ideally sized for the average automobile or truck. The attractive features of this type of vehicle security barricade are:

1. It safely prevents vehicle admission without bodily harm (reducing the risk of accidental injuries).
2. It can be permanently installed underground representing no obstruction or eyesore when not in use. When activated, a nylon or steel net can be quickly raised to engage the intruding vehicle.
3. It can be manually activated from remote sites once an intrusion is detected (by radio remote control if required).
4. It can be made mobile for transport to new locations and installed within an hour if required. It can use stored energy to remain independent of external power sources.

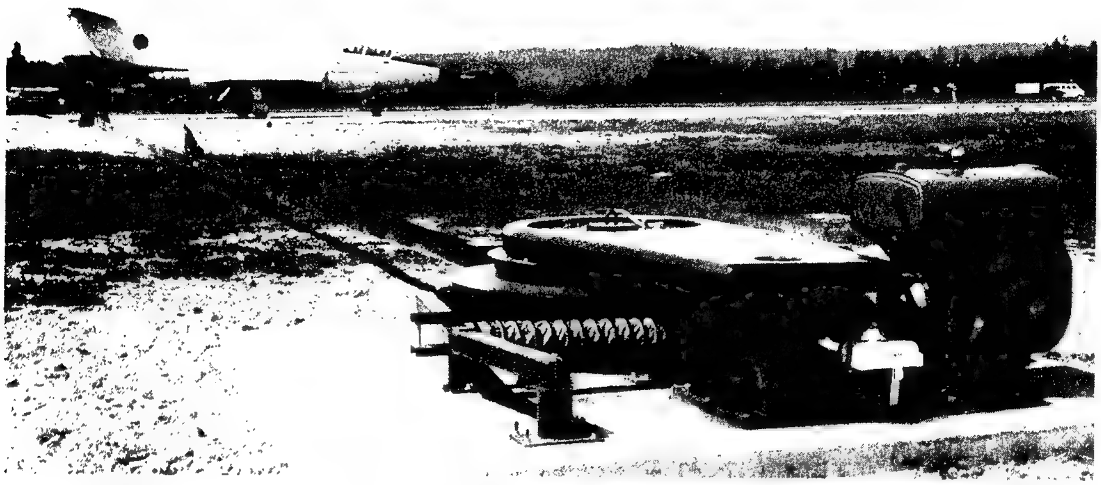
### CURRENT RESULTS

AAE has supplied water turbines to the University of New Mexico (under contract to Kirkland AFB) for a security barricade test program.

### CONTINUING DEVELOPMENT AND CONCLUSION

AAE believes that this type of system will be very attractive to people with physical security concerns. AAE will continue private R&D to further develop this concept into a commercial system and will market it in the U.S. and throughout the world.

# MODEL 44
# WATER TWISTER



Model 44 series Water Twister (reg. T.M.) brakes are currently used as arresting gear energy absorbers by the air forces of over 20 nations. The ten basic Model 44 variations (see table on overleaf) will satisfy the vast majority of aircraft needs. However, the versatile 44-inch diameter unit can easily be customized to meet any special requirements of the user's aircraft inventory.

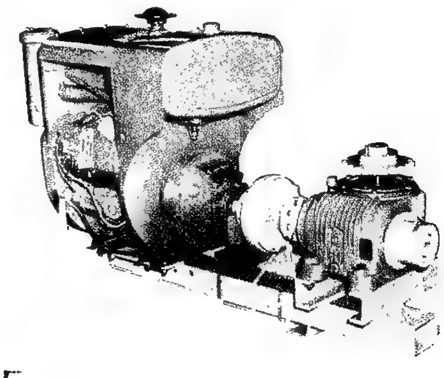
The Model 44 brakes are configured in three types of engagement systems: 1) Pendants (cross runway cable) for aircraft with tailhooks, 2) Net for other jet aircraft, and 3) Combined Net/Pendant where a mix of aircraft exists.

Model 44 arresting gears are used under both tactical operations, where every landing is arrested, and as simple emergency arresters where the gears remain ready for use but un-attended for long periods. The tactical application requires the use of rapid rewinding and fluid cooling accessories. The bare emergency arrester is capable of 4 maximum energy arrest-ments per hour without external cooling.

The Model 44 can be permanently installed on concrete foundations, or on the ground and anchored by cruciform stakes specially developed for the purpose. It is also available in a trailer mounted version for rapid overland mobility.

The Model 44 is rugged, reliable and nearly maintenance free. It is big enough to arrest 36,000 kilogram aircraft, but is compact enough to be easily transported by truck or helicopter. Its dependability is proven by over 4500 safe engagements every year, and it has made successful arrestments at speeds exceeding 407 kph (220 knots).

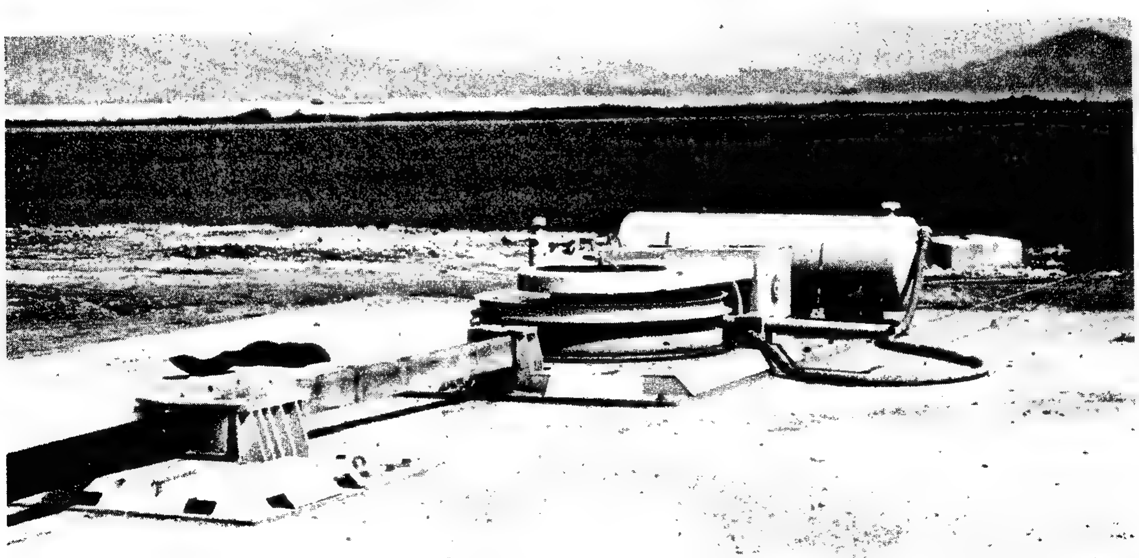
Gasoline powered rewind system for Model 44 provides retrieve times of 1-1/2 to 3 minutes.



## PERFORMANCE

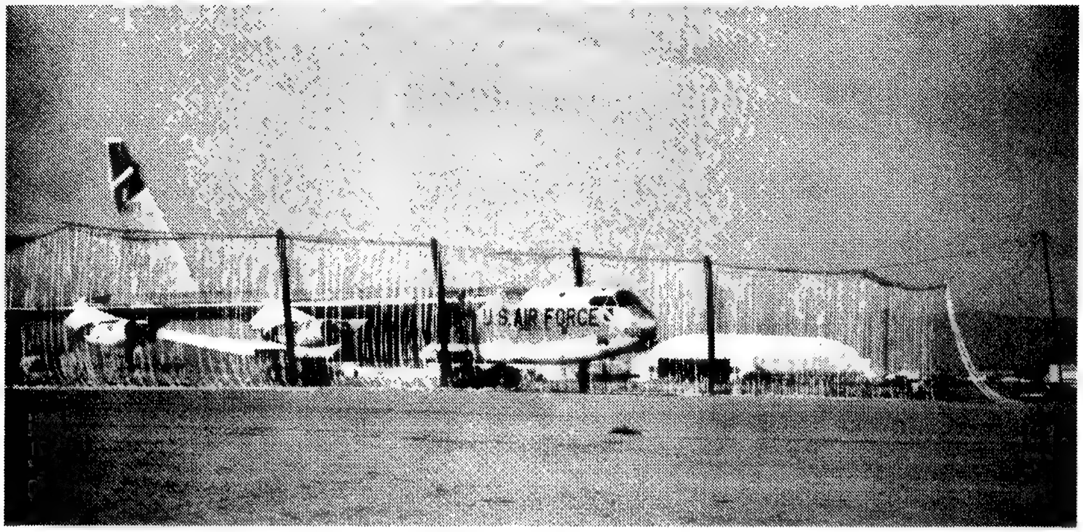
The following table lists the basic Model 44 configurations and their performance.

| Model 44 Configuration | Aircraft Weight | Engaging Velocity | Runout |
|---|---|---|---|
| 44B-2C | 22,700 kg (50,000 lbs)<br>12,700 kg (28,000 lbs) | 278 kph (150 k)<br>352 kph (190 k) | 270 m (886 ft) |
| 44B-2D | 27,300 kg (60,000 lbs)<br>18,000 kg (40,000 lbs) | 315 kph (170 k)<br>352 kph (190 k) | 270 m (886 ft) |
| 44B-2E | 27,300 kg (60,000 lbs)<br>16,000 kg (35,000 lbs) | 315 kph (170 k)<br>352 kph (190 k) | 335 m (1100 ft) |
| 44B-2F | 22,700 kg (50,000 lbs)<br>16,000 kg (35,000 lbs) | 315 kph (170 k)<br>352 kph (190 k) | 270 m (886 ft) |
| 44B-2H | 18,000 kg (40,000 lbs)<br>12,700 kg (28,000 lbs) | 296 kph (160 k)<br>352 kph (190 k) | 320 m (1050 ft) |
| 44B-2I | 33,500 kg (74,000 lbs)<br>18,000 kg (40,000 lbs) | 278 kph (150 k)<br>352 kph (190 k) | 305 m (1000 ft) |
| 44B-3A | 22,700 kg (50,000 lbs)<br>16,000 kg (35,000 lbs) | 278 kph (150 k)<br>306 kph (165 k) | 366 m (1200 ft) |
| 44B-3H | 27,300 kg (60,000 lbs)<br>18,000 kg (40,000 lbs) | 296 kph (160 k)<br>352 kph (190 k) | 328 m (1075 ft) |
| 44B-4C | 36,400 kg (80,000 lbs)<br>22,700 kg (50,000 lbs) | 278 kph (150 k)<br>333 kph (180 k) | 305 m (1000 ft) |
| 44E | 18,000 kg (40,000 lbs)<br>12,700 kg (28,000 lbs) | 278 kph (150 k)<br>352 kph (190 k) | 200 m (656 ft) |



SHANNON, IRELAND

# MODEL 64 RUNWAY SAFETY SYSTEM

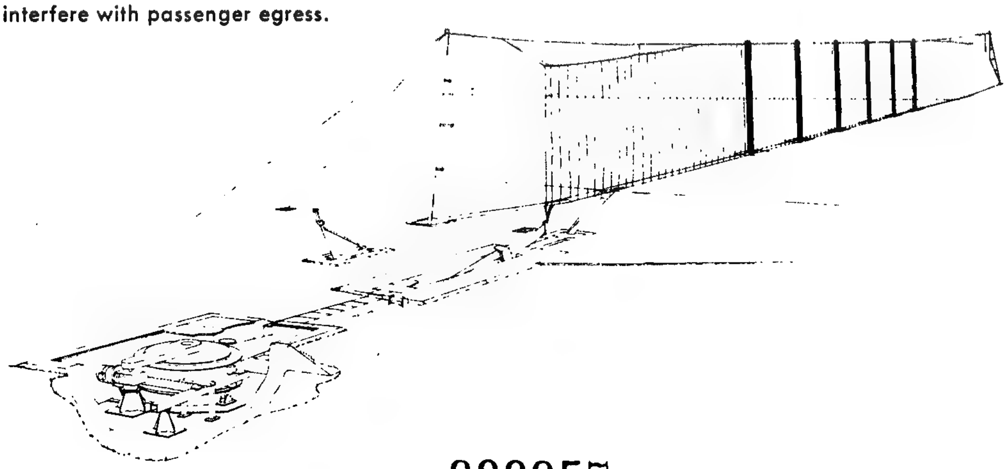



The Safeland Model 64 Runway Safety System is a completely flush-mounted emergency aircraft arresting gear which uses rotary hydraulic energy absorbers and a nylon barrier net for engagement. The System will safely arrest jet transports in aborted takeoff or landing emergencies with less than 1.5 g's deceleration. The deceleration and runout can be tailored to the available overrun area (see curves on reverse side).

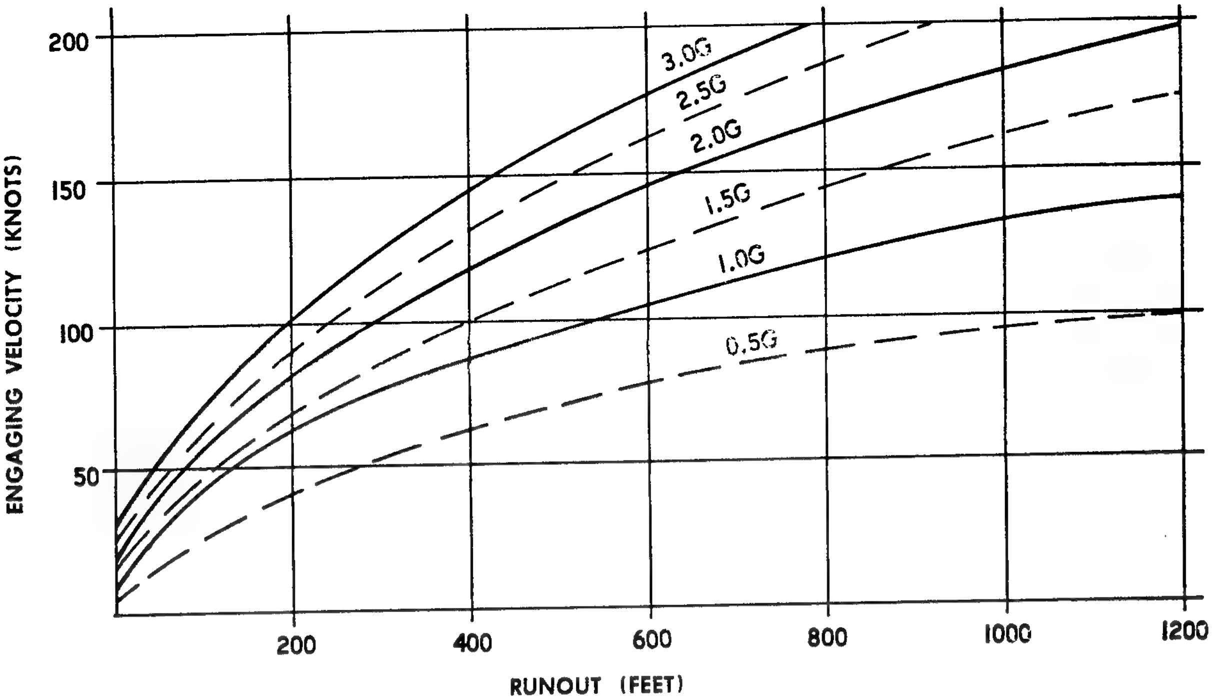
The Safeland Model 64 System is available in three civil configurations: one for a maximum aircraft weight of 200,000 pounds; another for 400,000 pound aircraft; and a tandem system which extends the capacity to 800,000 pounds.

All components are installed in covered subsurface housings capable of withstanding wheel rollover loads. Further weather protection is provided by sump pumps and electric heaters (30 KW) where required. Net erection reliability is insured by circuitry and system redundancy. It will erect in 1.7 seconds and is failsafe in the retracted mode.

In an arrestment, the aircraft nose penetrates the vertical straps of the net with total wing envelopment occurring prior to actuation of energy absorbers. The symmetrical net distribution prevents load concentrations. To reopen the runway, the net can be disconnected from the energy absorbers and the aircraft towed or taxied clear while still in the net. After arrestment, the net does not interfere with passenger egress.



## RUNOUT VS. ENGAGING VELOCITY




## MODEL 64 RUNWAY SAFETY SYSTEM

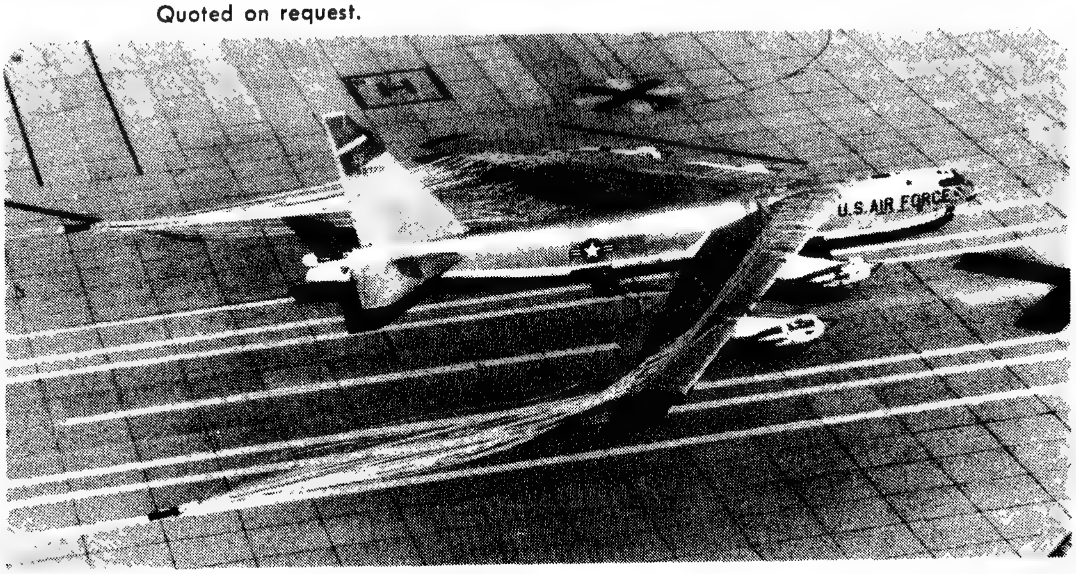
| | |
|---|---|
| <u>Triggering System</u> | |
| Trigger | Automatic, with Tower override |
| Sensors | Photo-electric (4 cells) |
| Computer | Electronic, redundant circuitry |
| Power | 1 KW (standby batteries standard) |
| <u>Erection System</u> | |
| Power | Pneumatic |
| Runway Stanchion | Inflated rubber (frangible) |
| Net erection time | 1.7 seconds |
| <u>Energy Absorbers</u> | |
| Type | Rotary hydraulic "Water Twisters"® |
| Nylon Tape Strength | 400,000 pounds |
| Retrieve | Electric - standard (10 KW) |
| <u>Barrier Net</u> | |
| Material | Nylon strap, ⅛" x 1" wide |
| Strap Strength | 6000 pounds |

<u>Delivery</u>

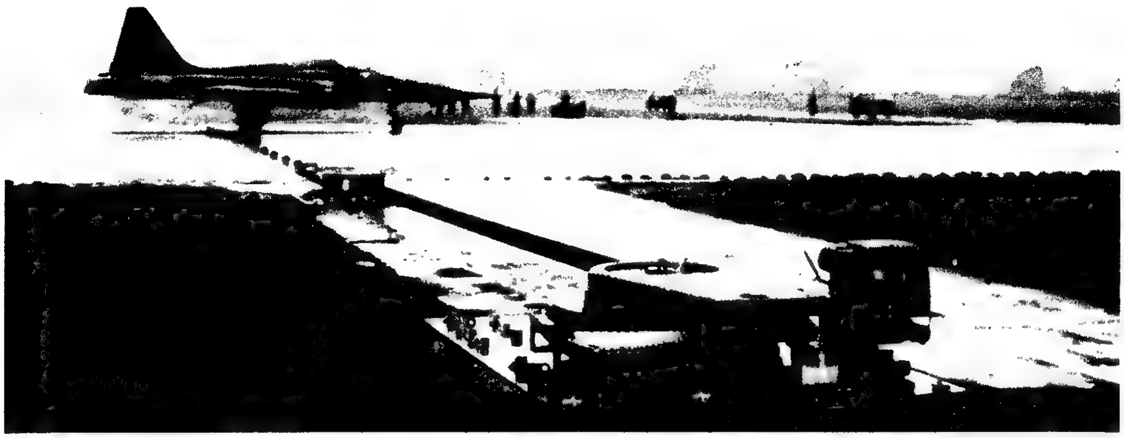
A Model 64 System can be delivered and installed 12 months after receipt of order.

<u>Cost</u>

Quoted on request.



# MODEL 34B WATER TWISTER



The Model 34B Water Twister (Reg. T.M.) brakes were developed primarily for runway arresting gear systems for lightweight, high performance jet aircraft.

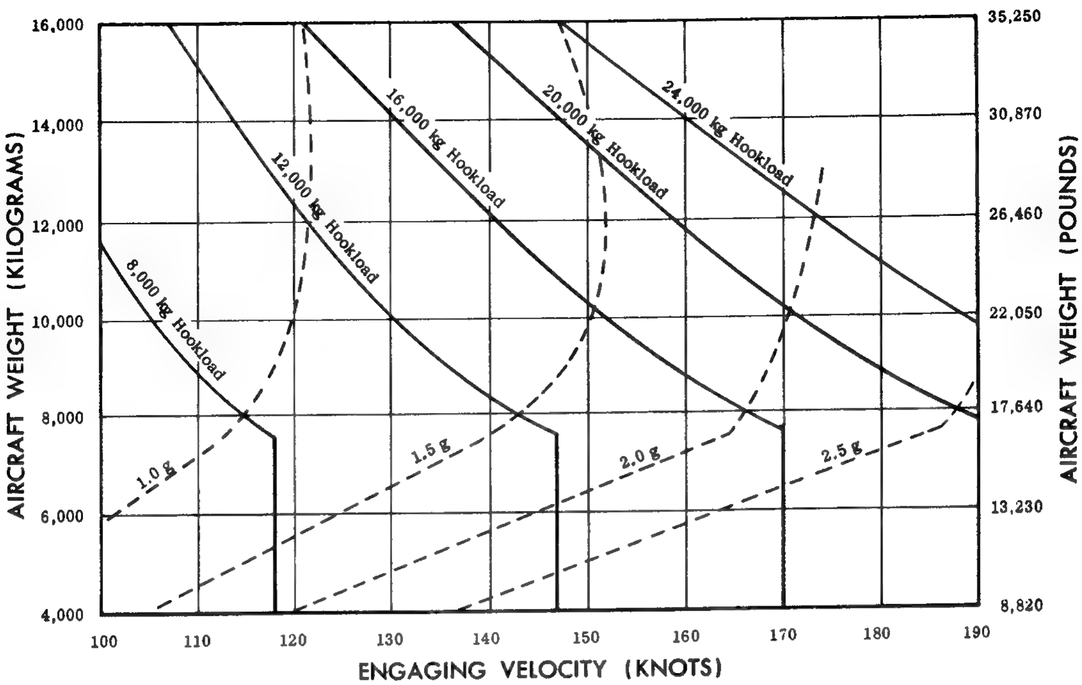
Model 34B systems are currently in operational service throughout the world.

The design range of the Model 34B includes 6,000 to 14,000 kilogram aircraft such as the F-5, Alpha Jet and the F-104. Under controlled test conditions, the Model 34B has arrested a test vehicle weighing more than 22,000 kilograms. Design engaging velocity is 170 knots.

Many accessories for the Model 34B, such as powered rewind or cooling subsystems, are interchangeable with the larger Model 44 series. The Model 34B can be used in emergency or rapid cycle operations, requires little maintenance, has no controls and can be left unattended and ready for long periods.

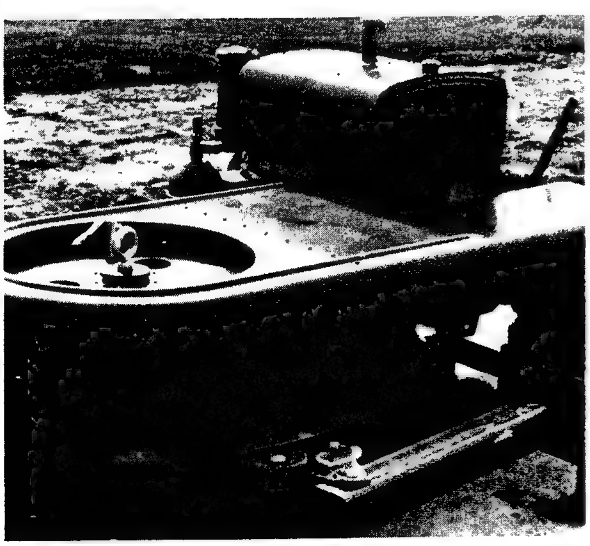
The compact size provides simple installation on either permanent concrete foundations or on bare earth with accessory base plates and cruciform stakes.

## MODEL 34B PERFORMANCE



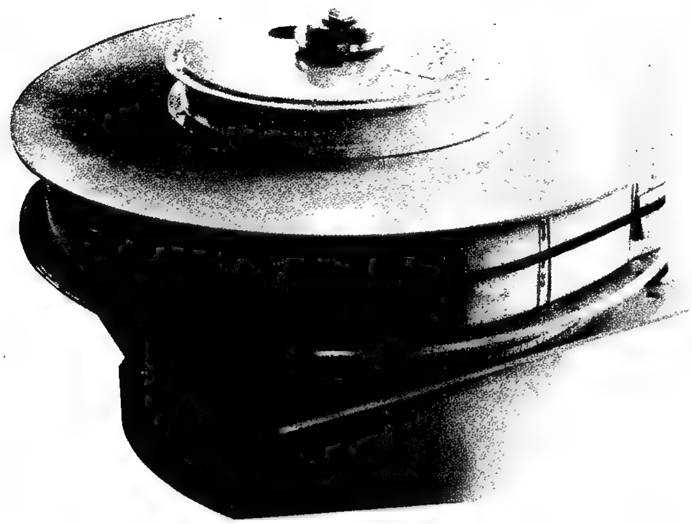

## MODEL 34B GENERAL SPECIFICATIONS

| | | | |
|---|---|---|---|
| Maximum engaging velocity | 352 kph (190 knots) | Pendant support (recommended) | rubber disk type |
| Design engaging velocity | 315 kph (170 knots) | Purchase tape size (nylon) | 15.25 cm wide x .635 cm thick |
| Runout (maximum) | 270 meters (886 feet) | Tape strength (ultimate) | 32,000 kilograms (70,500 pounds) |
| Pendant construction | 18 x 7 non-rotating wire rope | | |
| Pendant size: st'd. | 1.90 cm (¾ inch dia.) | Retrieve - powered | Internal combustion or electric |
| alt. | 2.54 cm (one inch dia.) | Retrieve - manual | Capstan |
| Pendant strength (nominal | | Pretension holding | Manual over center latch |
| breaking): st'd. | 21,792 kilograms (48,000 pounds) | Cycle time | 3 minutes powered<br>10 to 15 minutes manual |
| alt. | 38,318 kilograms (84,400 pounds) | Temperature limits | −40° to 70°C (−40° to 158°F) |
| | | Fluid capacity (per absorber) | 117 liters (45 gallons - U.S.) |



AIRCRAFT ARRESTING SYSTEMS

# WATER TWISTER BRAKES

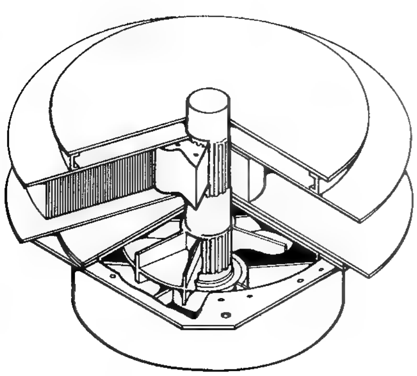


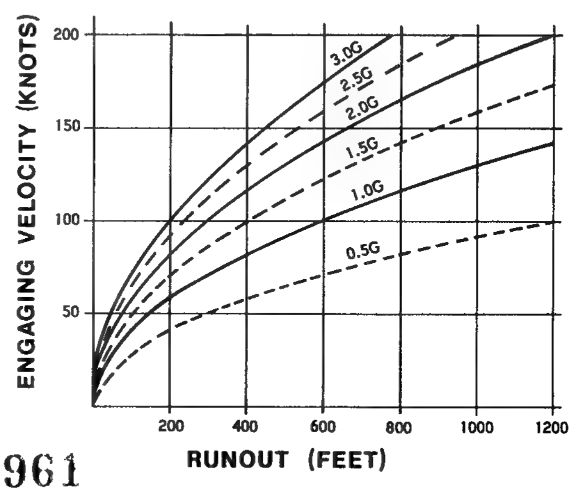
## GENERAL DESCRIPTION

The Water Twister (reg. T.M.) is a simple water brake that converts kinetic energy to heat through turbulence. The brake consists of a fluid filled steel casing, with internal stator vanes, which houses a vaned centrifugal rotor. The rotor is mounted on a shaft which extends out of the top of the casing. A storage reel for a nylon tape purchase element is mounted on and splined to the top end of the rotor shaft. The tape is wrapped on this storage reel, layer on layer, forming a spiral wrap. Pulling the tape off the reel causes the shaft and vaned rotor to revolve within the fluid filled casing, creating turbulence.

Standard Water Twister casing sizes range from 18-inch diameter to 64-inch diameter units. Their design provides a wide performance envelope in the respective standard sizes. However, specific energy absorbing requirements can be met by low cost modification of rotors, tapes or tape reels. Likewise, in aircraft arresting gear applications, runout can be tailored to meet any airport space limitations (see curve below).

**RUNOUT VS. ENGAGING VELOCITY**



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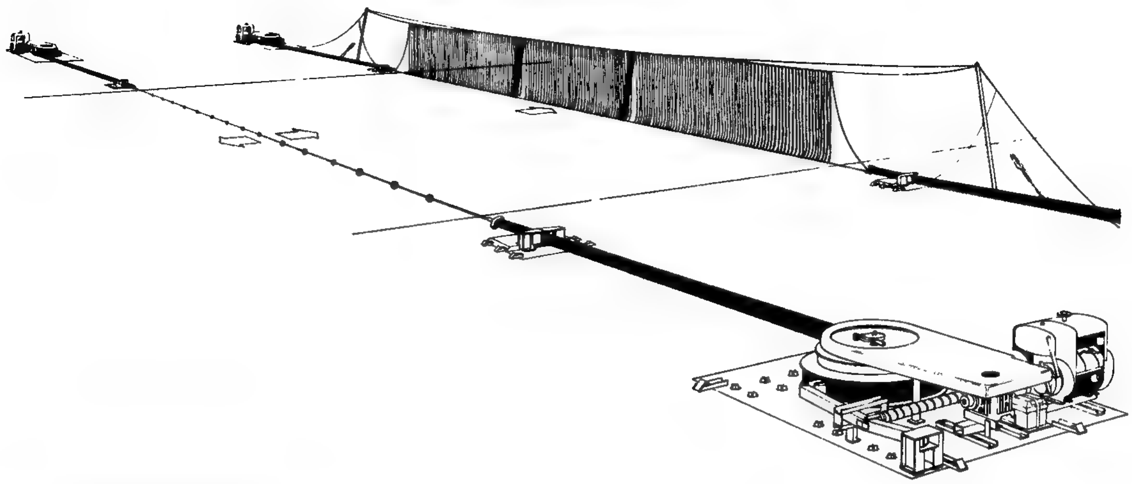
## WATER TWISTER ARRESTING GEAR

In aircraft arresting gear applications, two Water Twisters are installed opposite each other across a runway with the free ends of the purchase elements joined by a cross runway member.



## ENGAGEMENT

Cross runway members engage the aircraft. Water Twister arresters can be supplied with steel cable or nylon runway pendants for use with aircraft with tailhooks. Aircraft without hooks may be arrested by nylon barrier nets which envelop the entire aircraft. Water Twisters can be used with either pendant or net or with both. Rapid cycle tactical operations require pendants and tailhook equipped aircraft.

## PERFORMANCE

Water Twister brakes do not fade; the decreasing radius of the spiral tape wrap tends to maintain rotor velocity throughout an arrestment. They are bi-directional in operation and can arrest aircraft in quarter-span off-center engagements.

Water Twister reliability has been proven in thousands of arrestments in arctic, temperate, and desert environments. The energy absorbers are virtually maintenance free and require no controls or adjustments. The system may be left unattended in the ready position. There are no interface surfaces to wear during use. The operating fluid is a mixture of corrosion-inhibited ethylene glycol and water that does not deteriorate or change characteristics through use.

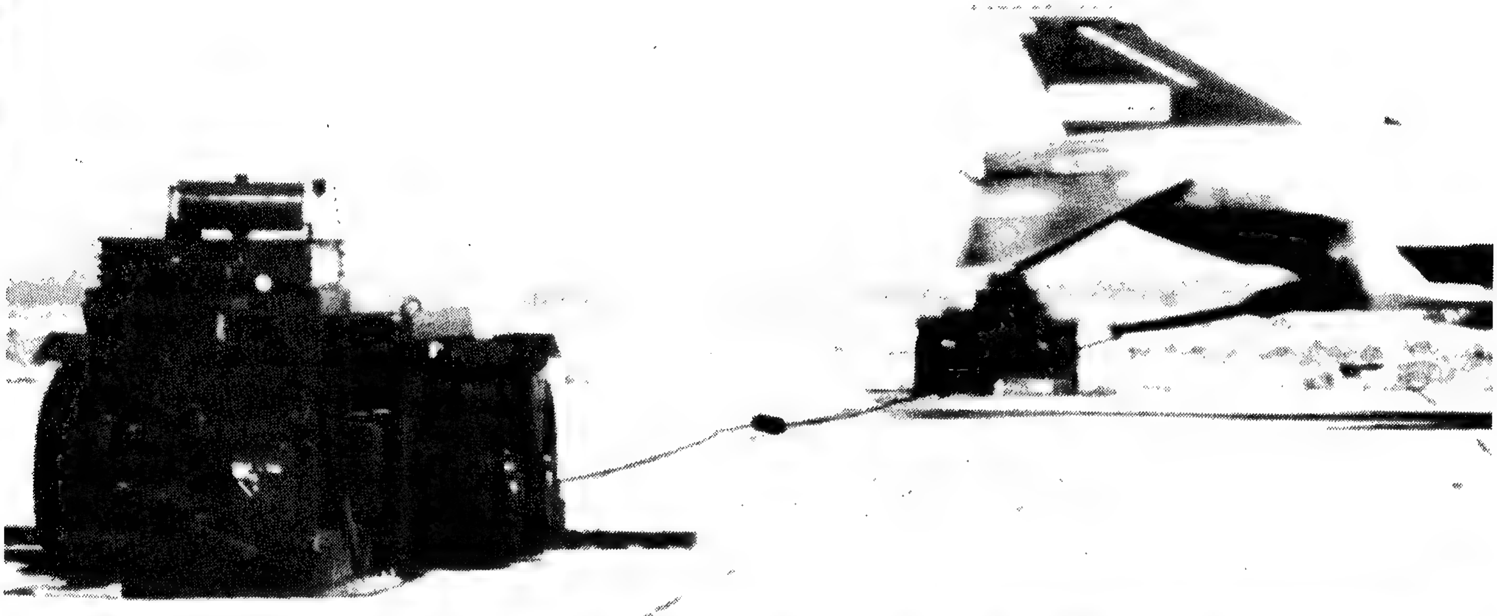
## INSTALLATION

The arresting system can be used for emergency or tactical application. It may be installed permanently in prepared locations or transported by truck or helicopter to remote tactical airstrips and installed with earth anchors and stakes.

## REWIND

Water Twisters may be retrieved with the standard capstan on the tape reel or by a power retriever. Retrieve power depends on recycle time requirements; retrieve power plants available include gasoline, diesel, or electrical motors. Auxiliary cooling systems are also available for rapid cycle operations.

ALL AMERICAN ENGINEERING COMPANY



# Mobile Arresting Gear

000963

*The Mobile Arresting Gear is a product of All American Engineering Company of Newark, Delaware, the world's leading developer and producer of aircraft arresting systems. MAG was developed to support Rapid Runway Repair and Rapid Deployment operations as specified by the United States Air Force. The basic system requirements are:*

*Air Transportable*

*Ground Mobile*

*Rapid Installation*

*Operational (i.e., arrestment every landing)*

*Operate on forward, battle-damaged or makeshift (sections of highway) runways*

*All American's MAG system meets these requirements with the features described in this brochure.*

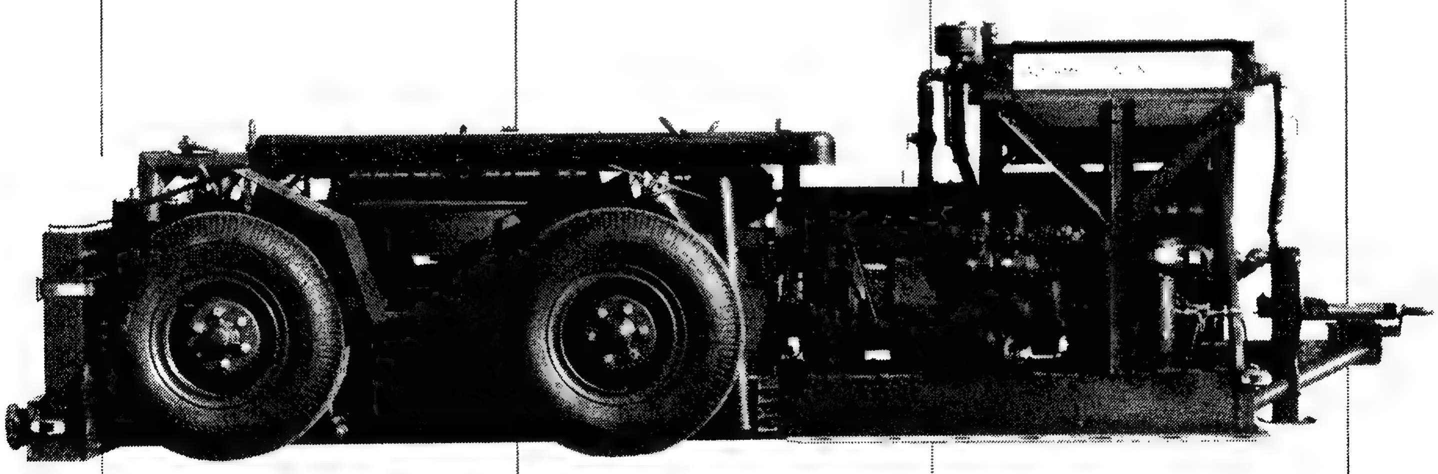
## Mobility

Complete MAG system can be carried in one C-130.

MAG units (2 per system) can be towed by any military vehicles with standard pintle on paved or unimproved roads.

MAG units have dual independent axles and self-actuating brakes (no connection to mover required).

MAG tire loading is compatible with C-130, C-141 and C-5A aircraft.



No disassembly, palletizing or packing required for air transport; units have integral tiedown points.

Up/down pivoting MAG drawbar permits ramp loading/unloading.

## *Reliability/ Maintainability*

The MAG is reliable; it is based on rotary hydraulic energy absorbing arresting gear technology pioneered by All American.

Hundreds of rotary hydraulic Water Twister® runway arresters in service with U.S. and other air forces worldwide.

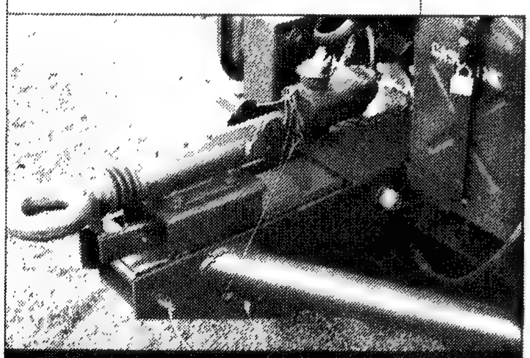
Emergency arrestments on Water Twisters number in thousands annually.

Water Twisters use turbines in fluids to absorb energy; there are no friction surfaces to wear and replace, no cams or valves to break, foul or freeze.

When rewound (retrieved), Water Twisters are *ready;* no adjustments are needed to synchronize units.

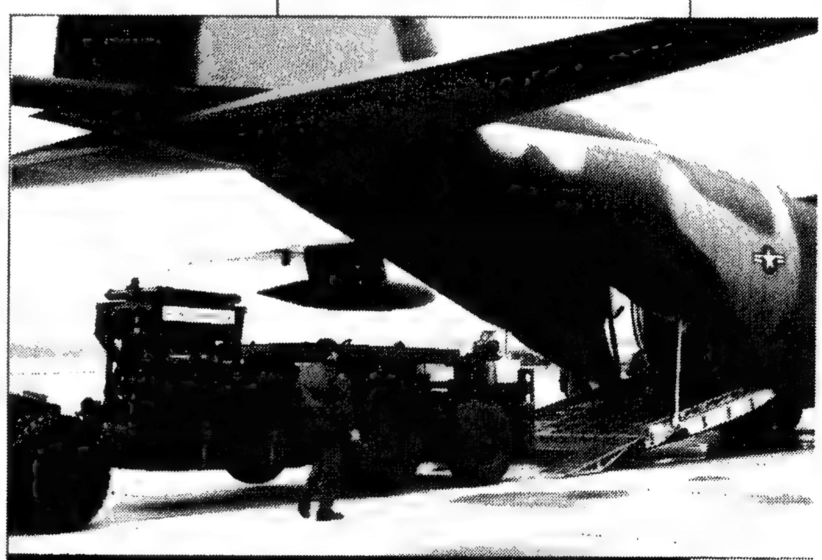
Water Twister energy absorbers have only one moving assembly; maintenance is minimal and requires no special skills.

MAG can be operated, maintained by crews in arctic or CWD clothing.



*MAG drawbar senses tow loads, applies and releases brakes automatically.*

*MAG system in C-130*



*Loading onto aircraft ramps eased by MAG drawbar that pivots in vertical plane.*

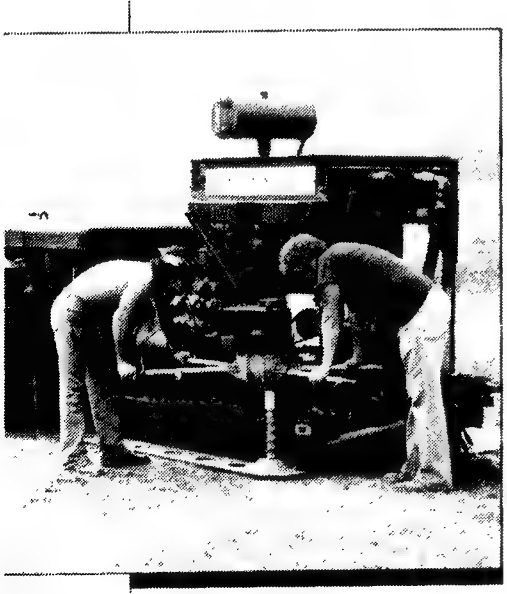
## *Quick Installation*

MAG's are easily towed to installation site.

Pneumatic suspensions kneel to lower units to surface for anchoring.

Can be installed on concrete, blacktop or soil surfaces.

Anchors quickly with on-board tools, anchors (demonstrated 25 minutes to ready-to-arrest at Edwards AFB).



*Gasoline powered auger with MAG drills holes for anchoring.*

## *Operational*

MAG is *rapid cycling*.

Powered retrieve rewinds purchase tapes on storage drums.

Cross runway engagement cable positioned when purchase tapes rewound.

System pretensioned automatically when retrieve clutch disengaged.

Retrieve time for MAG shown here is 70 seconds (1150 ft. tapes)

*Aft view of MAG unit shows stakes and engaging cable stowed, unit ready for travel.*

*MAG anchors in soil installations with stakes; stake driver is supplied on board each unit.*

ALL AMERICAN
ENGINEERING
COMPANY

## *Continuous Operation*

Each MAG unit's closed loop cooling system can dissipate 900 × $10^6$ ft./lbs. of energy/hour; equivalent to 20 arrests/hour of 40,000 lb. aircraft @ 160 knots.

## *Air Force Proven*

The aircraft arrestments shown here were performed by the USAF at Edwards AFB.

## *Each MAG unit is completely self-contained and equipped with:*

65 HP engine to power the retrieve drive, on-board air compressor, cooling system, and electrical supply.

Lights for night operation.

Anchors for hard surface or soil installation.

Special power tools for installation and maintenance, including augers, combination drill/stake driver/breakers, drills/wrenches, and selected hand tools.

Air storage tanks.

Fuel tanks for prime power units and gasoline powered tools.

Hydropneumatic jacks (stake removal for quick redeployment).

*F-16 tailhook engages MAG cross runway cable in tests conducted by United States Air Force at Edwards AFB.*

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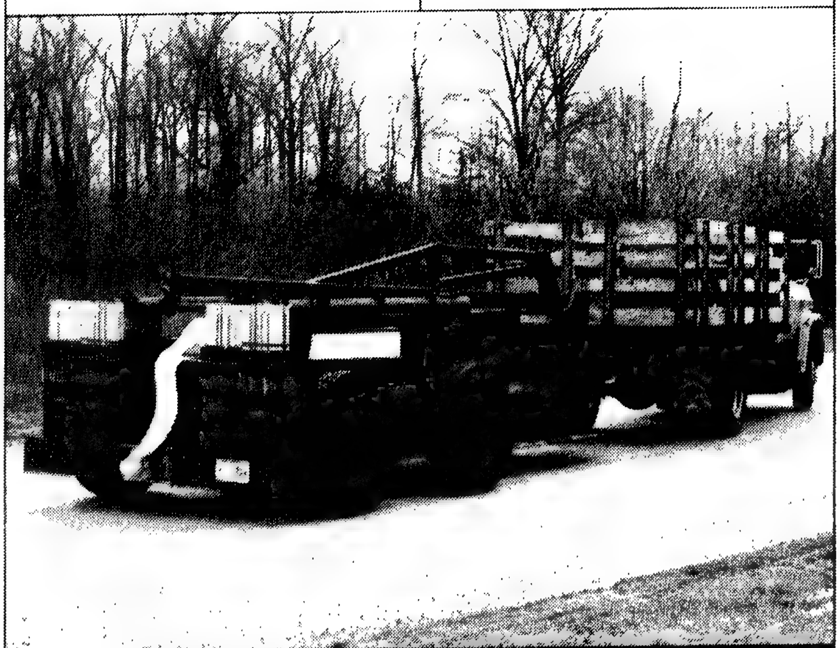
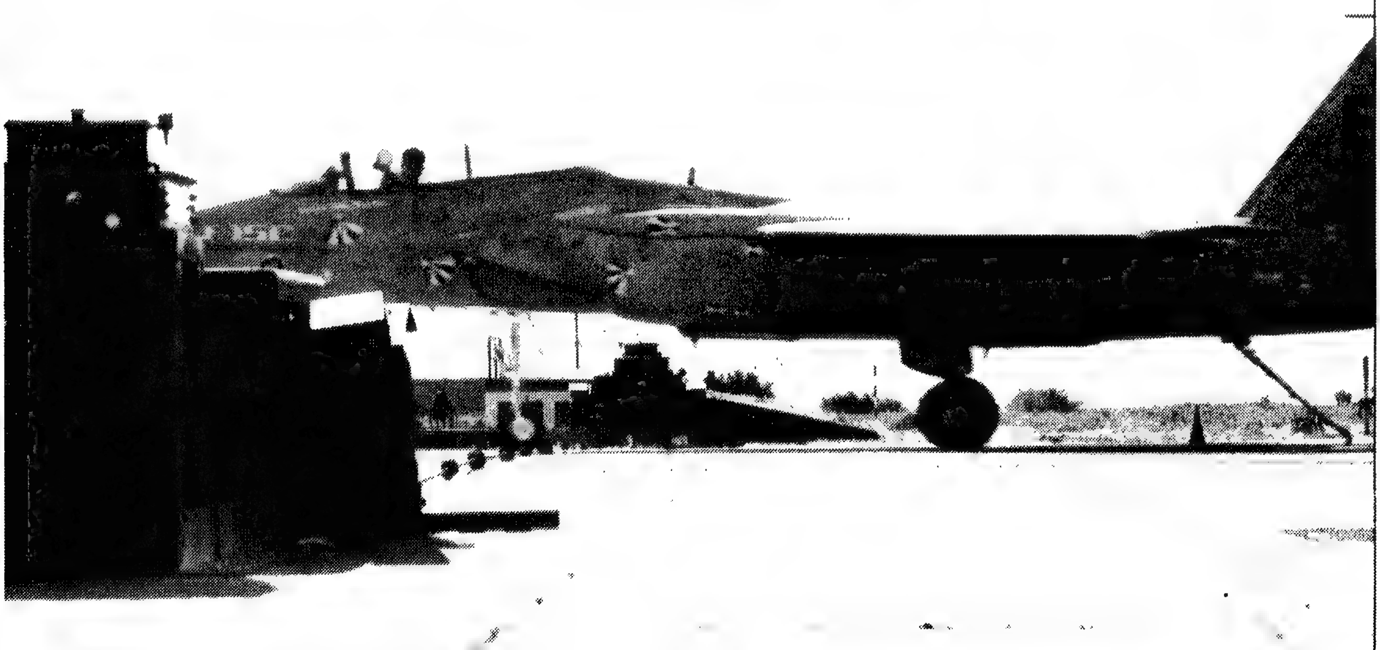


MAG*NET unit in transit.

MAG can be moved by vehicles with standard pintles.



F-15 with tailhook down about to engage bi-directional MAG cross runway cable in USAF tests.

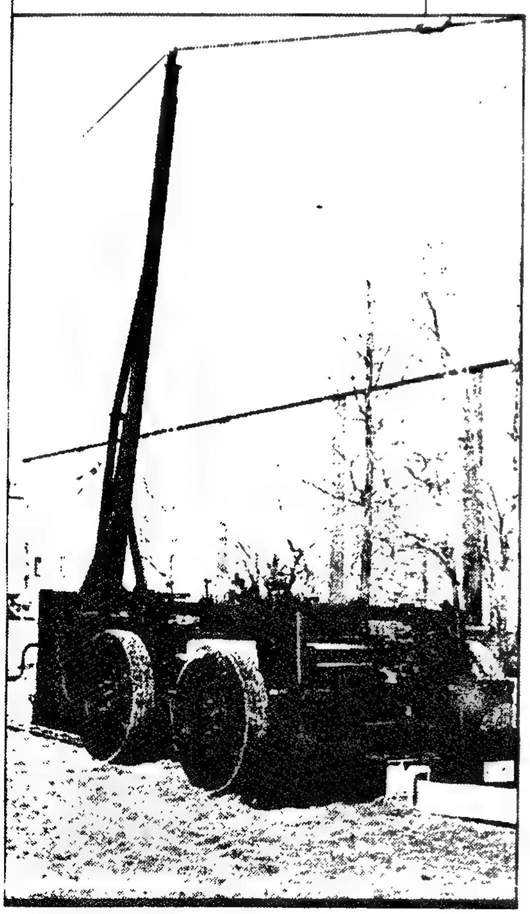
000968

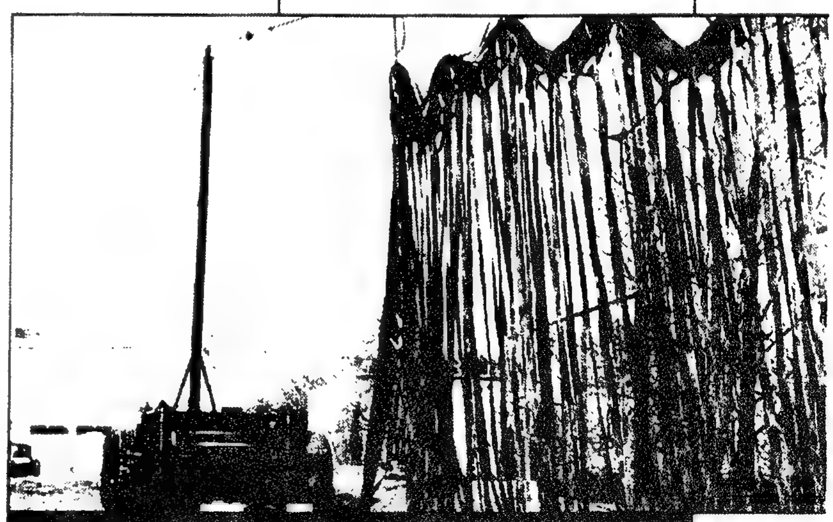
Many high performance military aircraft are not equipped with tailhooks and cannot be arrested by cable arresters such as the MAG. Likewise, an aircraft, with a tailhook, that has an emergency in which the hook is disabled cannot use a cable system.

To meet these situations, All American offers MAG*NET, a mobile net arresting system. MAG*NET is similar to the MAG arrester system shown on the previous pages, except that the cable is replaced with a net to engage, envelop and stop the aircraft. The net, which lies flat on the runway surface when not in use, is erected in less than 2 seconds by radio actuated stanchions mounted on the mobile arrester units.

MAG*NET has virtually all the features of the MAG discussed earlier; however, it utilizes a smaller retrieve engine since rapid cycling of a net arrester system is not possible. MAG*NET is also completely self-contained and does not require any external energy source, wires or plumbing for operation.

Both the MAG and the MAG*NET systems shown in this brochure are equipped with the use-proven Model 44 Water Twister®. The systems can be equipped with All American's Model 34 Water Twister® for lighter weight aircraft, such as the F-5 or Alpha Jet class. They can also use the USAF BAK-13 or the USN E-28, both of which are based on All American's rotary hydraulic energy absorbing technology.





*MAG*NET stanchions erect by stored hydropneumatic energy. On-board powered equipment supplies compressed air.*

*Engagement net is suspended from upper cable (see at left) between two MAG*NET units on opposite sides of runway. With stanchion down, net and cable are on runway surface, do not interfere with normal traffic.*

An International Controls Corp. company

For more detailed information on the MAG or MAG*NET systems, contact the Arresting Gear Department at any of the three addresses shown.

725 Dawson Drive
P.O. Box 9269
Newark, DE 19714
Telephone: (302) 453-8100
Cable: ALAMEN
TWX: 510-666-1018

OUTSIDE THE AMERICAS, CONTACT:

AAI INTERNATIONAL, LTD.
Berkshire House
Queen Street, Maidenhead, Berkshire
England SL6 1NF
Telephone: 32-005
Cable: ALAMINT
TLX: 847266

BEFAB SAFELAND, LTD.
Bay 15, Industrial Estate
Shannon, County Clare
Republic of Ireland
Telephone: SHANNON 61844
Cable: SAFELAND Shannon
TLX: 26242

AIRCRAFT ARRESTING SYSTEMS

# THE DEVASTATOR

**THE AMERICAN SECURITY FENCE CORPORATION PRESENTS:**

THE DEVASTATOR™ VEHICLE BARRIER

The *ASF Devastator™* vehicle barrier is designed to provide an effective and economical barrier to unauthorized vehicle entrance or departure from a controlled area. It is ideal for DOD facilities, DOE sites, embassies, defense contractors, airports, communication areas, and any highly sensitive or restricted area.

AMERICAN SECURITY FENCE

American Security
Fence Corporation
P.O. Box 6633
Phoenix, Arizona 85005
(602) 272-6606
TELEX: 187129 FENCE UT

ASF D1 4-86 2M
PRINTED IN USA

## DESIGN

The *American Security Fence Devastator*™ consists of a series of concrete filled impalers made from a 22½" by 53½" by .250" top plate which raises to a height of 26" above the road surface. With a 6" spacing between impalers, any combination of two or three point *ASF Devastator*™ units can be used to secure any size entrance.

## CONTROL

The *ASF Devastator*™ can be interfaced with access control, monitoring, and security systems to provide controlled access with an emergency up feature.

## INSTALLATION

The *ASF Devastator*™ can be quickly and easily installed. The unit is shipped complete from the factory, and set in place with approximately 3 yards of concrete per point. The unit is also available in MODULAR units for portable use where the system is set in place with ramps leading to and away from the unit.

AMERICAN SECURITY FENCE

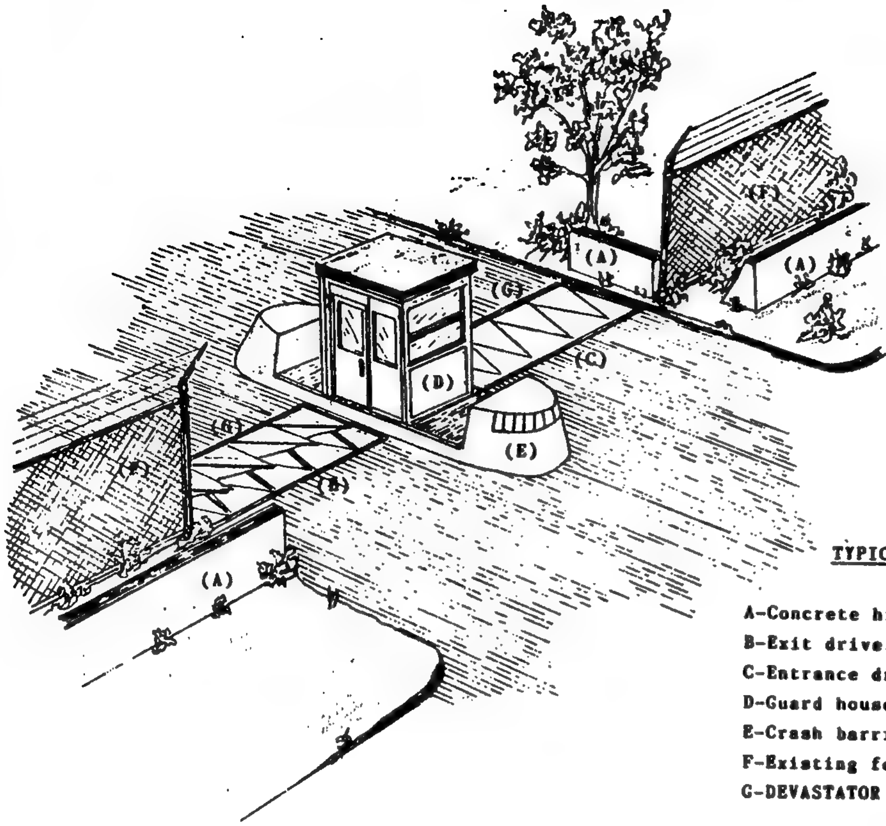
## OPERATION

The *ASF Devastator*™ is a passive system which means that its passive state is armed, and it is lowered by means of a manual or powered control. The impalers are raised by powerful compression springs and lowered by hydraulic pressure which can be manually or electrically controlled. This means the unit is never incapacitated by a power failure. It can even be used without power. As such, it is ideal for the seldom used or emergency gate where the desire is to have constant, unsupervised vehicle deterence. The *ASF Devastator*™ is also the choice for frequent cycle, main gate operation due to its ease of operation, reliability under any circumstance, and low cost.

American Security
Fence Corporation
P.O. Box 6633
Phoenix, Arizona 85005
(602) 272-6606
TELEX: 187129 FENCE UT

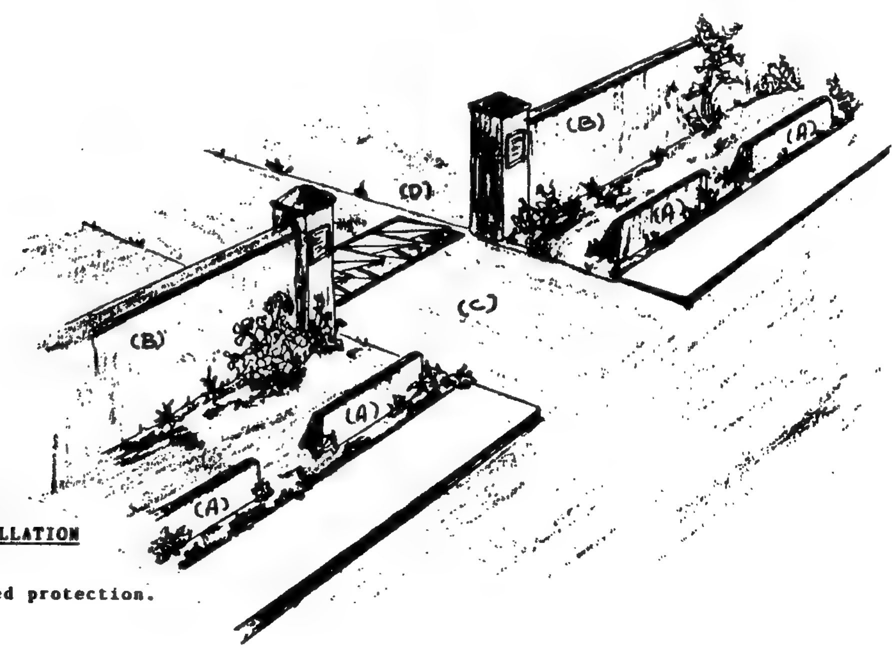
DISTRIBUTED BY:

# TYPICAL DEVASTATOR INSTALLATIONS




**TYPICAL DUAL DRIVEWAY INSTALLATION**

A-Concrete highway dividers for added protection.
B-Exit drive.
C-Entrance drive.
D-Guard house.
E-Crash barrier.
F-Existing fence or wall.
G-DEVASTATOR UNITS.




**TYPICAL SINGLE DRIVEWAY INSTALLATION**

A-Concrete highway dividers for added protection.

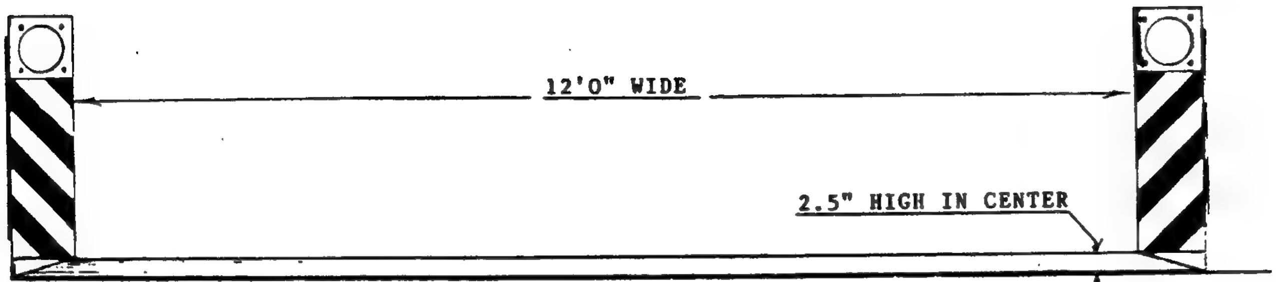
B-Existing wall or fence.

C-Existing driveway.

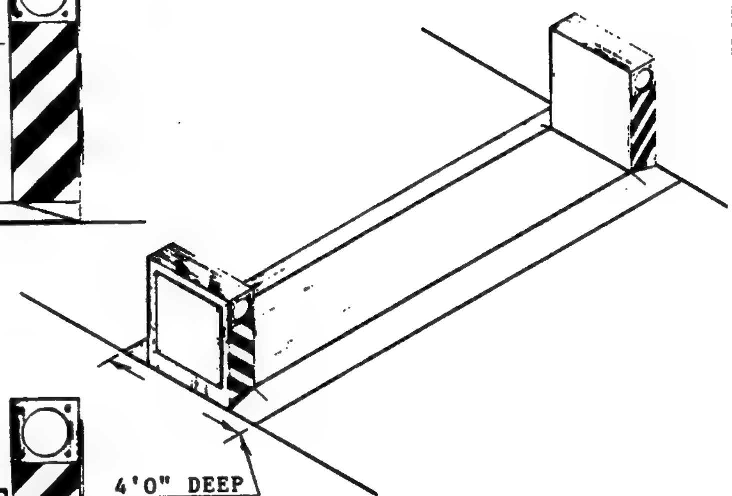
D-DEVASTATOR UNIT. Installed inside of posts and gates.

NOTE: For appearance, hedges can be planted in front of highway dividers.

# QUICK TRAP by TIRETRAP




STOP PLATE SHOWN IN DOWN POSITION



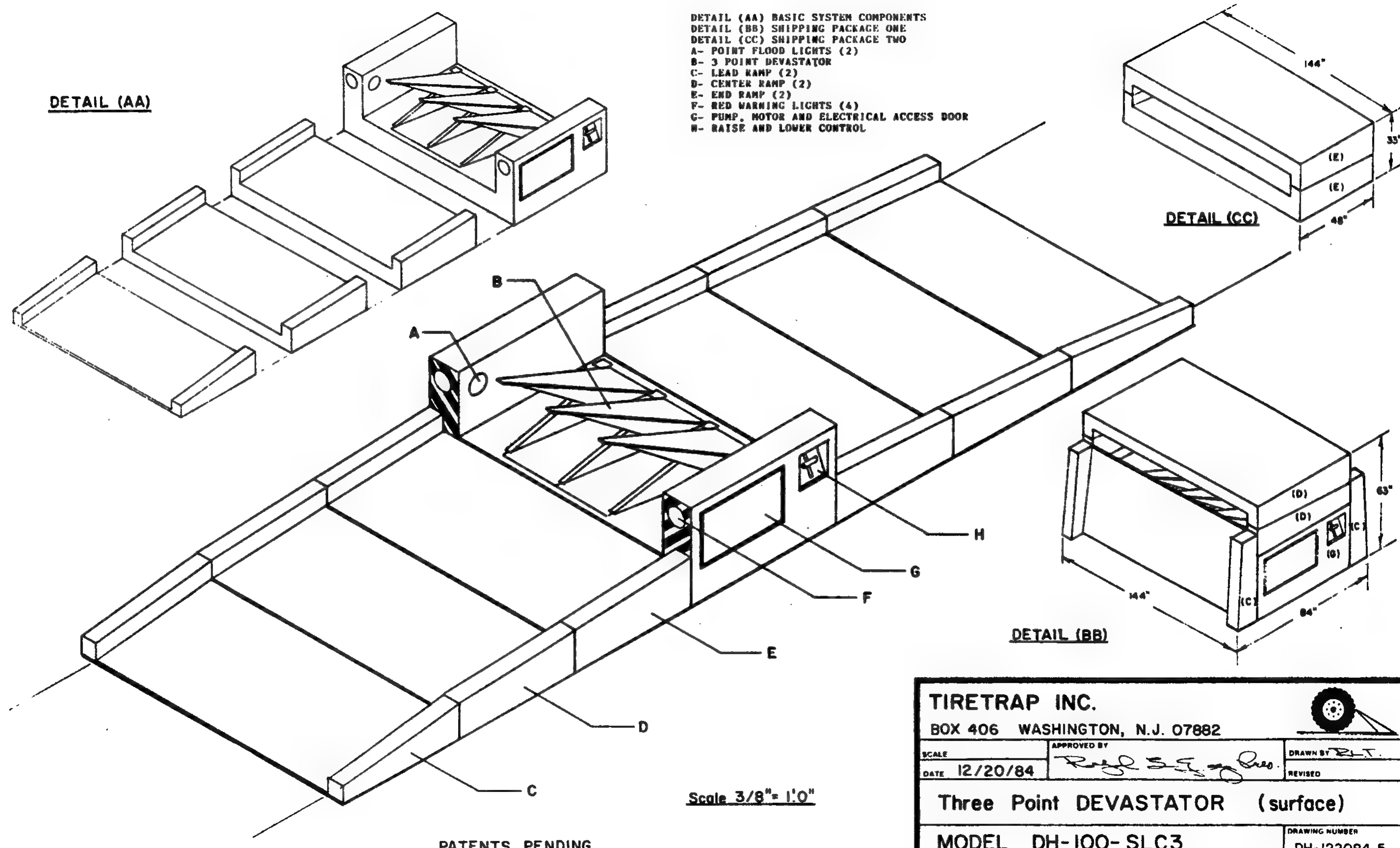

STOP PLATE SHOWN IN UP POSITION

PATENTS PENDING

TIRETRAP INC.

(212) 661-3960 ● (201) 689-5388

| | | |
|---|---|---|
| SCALE 3/4" = 1'0" | APPROVED BY | DRAWN BY |
| DATE 10-29-84 | | REVISED 10/21/86 |
| 211 E 43rd St Suite 2204 New York N Y 10017<br>R D 4 Box 149B Washington N J 07882 | | DRAWING NUMBER DT-01084-A |




DETAIL (AA) BASIC SYSTEM COMPONENTS
DETAIL (BB) SHIPPING PACKAGE ONE
DETAIL (CC) SHIPPING PACKAGE TWO
A- POINT FLOOD LIGHTS (2)
B- 3 POINT DEVASTATOR
C- LEAD RAMP (2)
D- CENTER RAMP (2)
E- END RAMP (2)
F- RED WARNING LIGHTS (4)
G- PUMP, MOTOR AND ELECTRICAL ACCESS DOOR
H- RAISE AND LOWER CONTROL

TIRETRAP INC.
BOX 406 WASHINGTON, N.J. 07882

| | | |
|---|---|---|
| SCALE | APPROVED BY | DRAWN BY R.L.T. |
| DATE 12/20/84 | | REVISED |

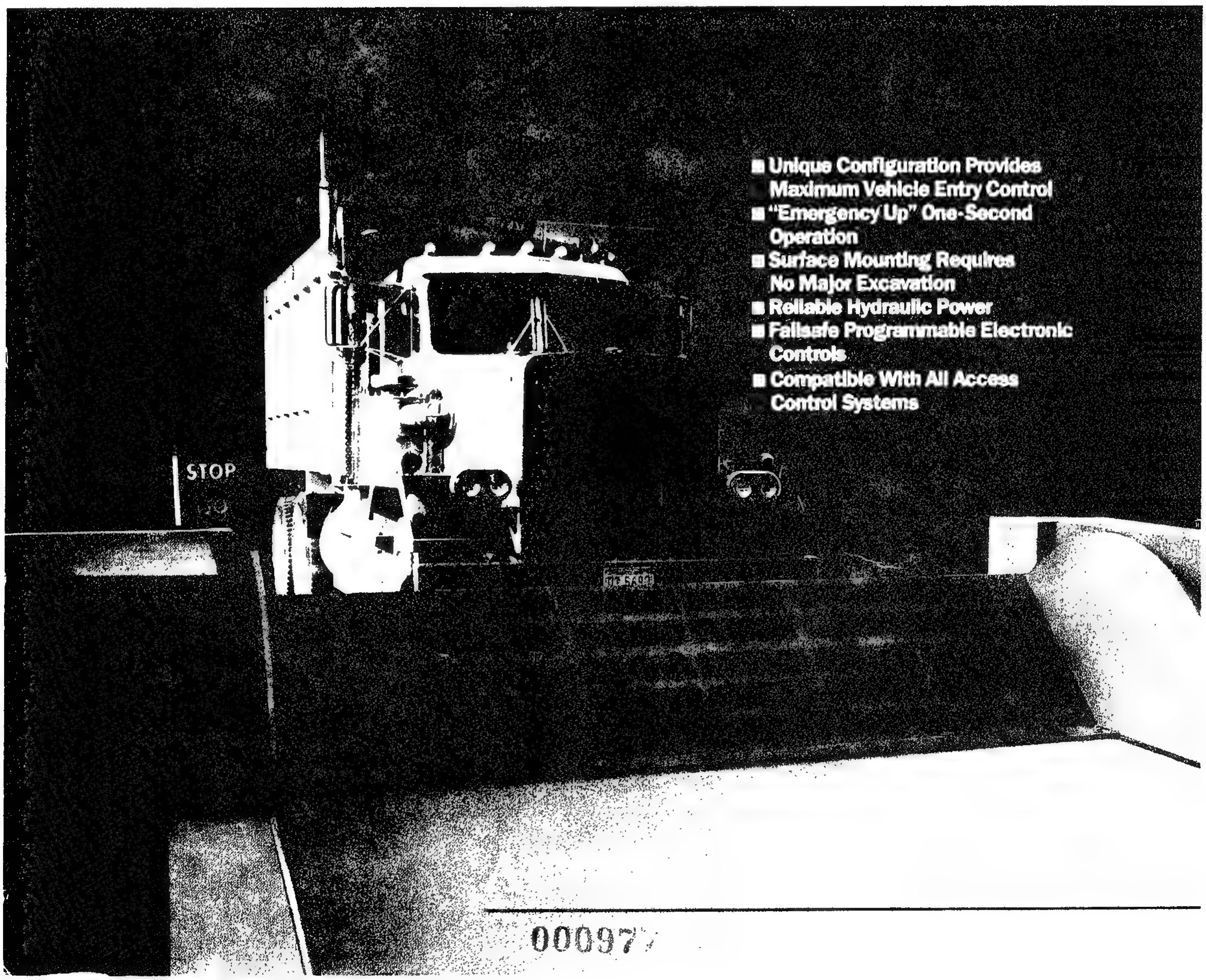
Three Point DEVASTATOR (surface)

MODEL DH-100-SLC3 — DRAWING NUMBER DH-122084-5

NASATKA

# MSB

## MAXIMUM SECURITY BARRIER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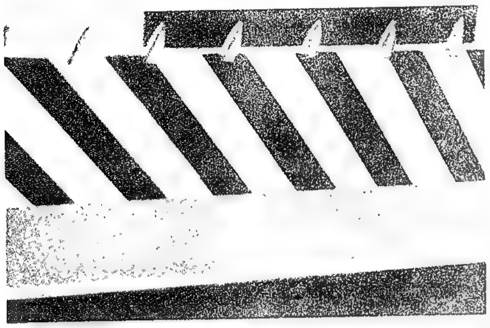
The MSB II provides effective control of vehicles entering or exiting any facility. The MSB II is designed as a high security access control device for private roads, airports, industrial plants, and as an anti-terrorist device for oil refineries, satellite communication stations, embassies, military bases, and other government installations.



The MSB II series barrier provides the highest degree of security against forced vehicle entry due to its force absorption design coupled with reliable hydraulic power and failsafe electronic controls. The barrier is designed so that the force of impact is absorbed by its large steel base plate and the roadway surface. The MSB II hydraulic barrier is able to absorb full vehicle impact at all points of its operational cycle. A system of 1″ steel plates and a 2″ diameter steel hinge bar ensures that a positive barrier is quickly in place to stop unauthorized vehicles. Since the security of the system is not dependent upon costly excavation, a MSB II can be installed in as little as 24 hours on an existing pad and later moved without roadway rebuilding.

The fully electronic programmable controller gives the system a wide range of functions to meet the most demanding application. The MSB II can be Guard controlled or operated by use of card readers, digital keypads, laser vehicle identification systems, radio controls, timers with magnetic vehicle detectors, or interfaced with existing security systems. It always provides positive control of the roadway with an important balance between "Safety and Security".

An "Emergency Up" mode of operation will place the barrier in the up position in approximately one-second. In the event of a power failure, a hydraulic accumulator and battery back-up allows the MSB II to operate up to 6 full cycles at normal operating speed, with complete electronic control. Additional cycles can be added with the manual hydraulic pump system. Hydraulic power is not required to maintain the barrier in the "Up" position.

Multiple barriers can be controlled from a single hydraulic power system. The system control can be easily programmed to allow alternate action, simultaneous action, or any combination of traffic control.

AutoMatic Operators' design consultants can integrate the MSB II with other access control perimeter protection devices to produce a broad range of security system configurations. Our experienced sales, engineering and service departments can provide you with design assistance, training seminars and technical support in perimeter access security systems.

***OPTIONS:***

- Manual Hydraulic Pump System (Continuous operation without power)
- Adjustable Cycle Operation Time (4 to 8 seconds)
- Tiger Teeth on Leading Edge
- Red/Green Traffic Lights and Warning Bells
- Timer/Safety Detector (Returns barrier to up position)
- High Speed Monitor Alarm System
- "Auto-Read Laser" Vehicle Identification System
- Access Control Systems and Closed Circuit T.V.

Designed & Constructed By:

NASATKA & SONS, INC.

Distributor:

AUTOMATIC OPERATORS

6500 Eastern Avenue
Baltimore, MD 21224

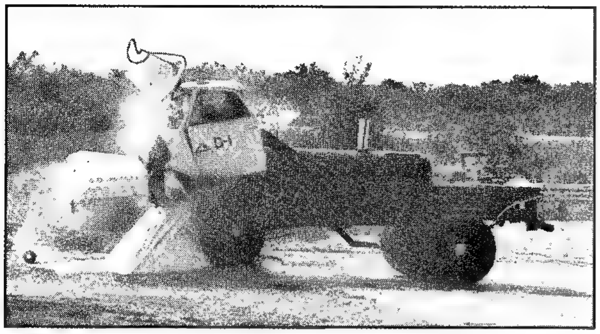
301-633-6509

Member of American
Society For Industrial Security

# **DELTA** Counter Terrorist Vehicle Barricade Systems

## To control authorized traffic and stop terrorist suicide attacks **Delta** offers 14 models of barricade systems covering the full range of security requirements and traffic regulation situations.

**Delta Barricade Systems have been tested in full scale configuration ten times and have met or exceeded the test requirements each time.** ***The results of four recent tests are shown below.***



**Date:** September 23, 1985

**Barricade:** Delta Model TT207S Phalanx
Width 108 in (2.74m) Height 38 in (.96m)

**Vehicle:** Chevrolet Truck CSD042
Gross Weight 15,000 lbs (6803 kg)
Impact Velocity 50.1 mph (80.6 km/h)

**Result:** Truck destroyed.
Barricade fully operational — superficial damage.

**Design Capacity:** 30,000 lbs (13608 kg) @ 50 mph (80.44 km/h)

**D.O.S. Assessment:** K12/L3.0

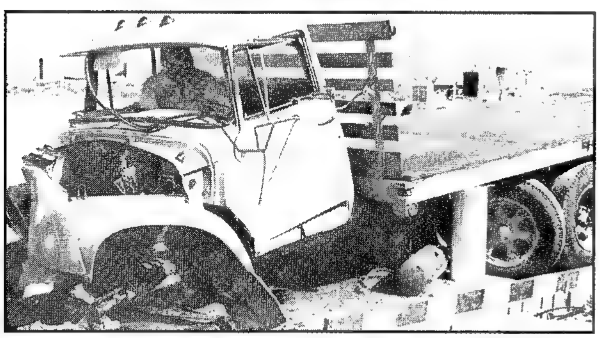
**Date:** November 26, 1985

**Barricade:** Delta Model TT212 Cable Crash Beam
Free opening 120 inches (3.05m)

**Vehicle:** U.S. Military Truck
Weight 10,100 lbs (4581 kg)
Impact Velocity 17.2 mph (27.2 km/h)

**Result:** Vehicle was stopped in under 30 inches (.76m) and was thrown back 48 in (1.2m)

**Design Capacity:** 6,000 lbs (2720 kg) @ 34.8 mph (56 km/h)

**Date:** February 13, 1986
**Barricade:** TT210 / TT210M Three Bollard Array
**Vehicle:** International Harvester Series 1700
Weight 15,180 lbs (6886 kg)
Impact Velocity 32 mph (51.5 km/h)
**Result:** Truck was destroyed.
Two bollards fully operational.
The third required less than 1 hour to restore to operation.
**Design Capacity:**
1 Bollard 10,000 lbs (4536 kg) @ 41 mph (65.9 km/h)
2 Bollards 10,000 lbs (4536 kg) @ 50.1 mph (80.6 km/h)
3 Bollards 10,000 lbs (4536 kg) @ 58 mph (93.3 km/h)
**D.O.S. Assessment:** K4/L2

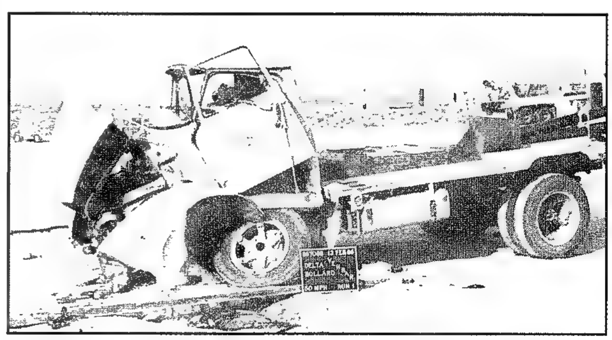
**Date:** February 13, 1986

**Barricade:** TT210 & TT210M Three Bollard Array

**Vehicle:** International Harvester Series 1700
Weight 10,000 lbs (4536 kg)
Impact Velocity 40 mph (64.4 km/h)

**Result:** Truck destroyed. Two bollards were fully operational. The third required 4.3 hours to repair.

**Design Capacity:**
1 Bollard 10,000 lbs (4536 kg) @ 41 mph (65.9 km/h)
2 Bollards 10,000 lbs (4536 kg) @ 50.1 mph (80.6 km/h)
3 Bollards 10,000 lbs (4536 kg) @ 58 mph (93.3 km/h)

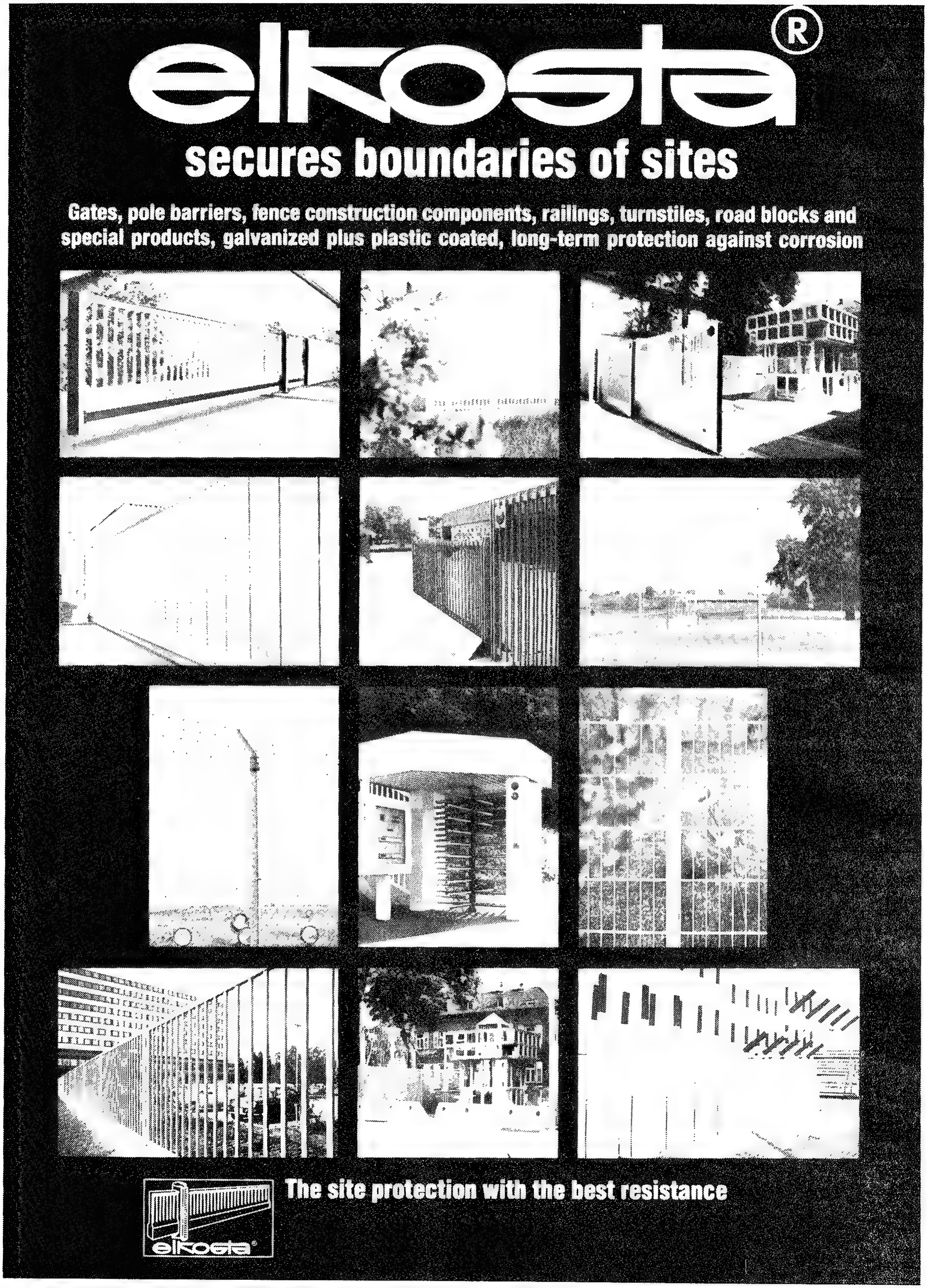


A video tape and engineering discussion of these tests is available on request. Delta provides engineering, design, installation and service world wide.

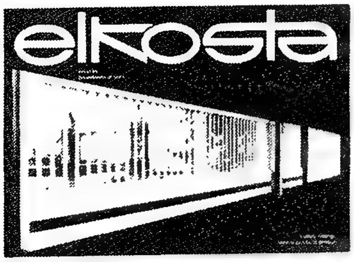
DELTA

**DELTA SCIENTIFIC CORPORATION**
2031 North Lincoln Street
Burbank, California, USA
Telephone: (818) 841-2787 / TELEX: 704283
Cable: DEL SCI CORP

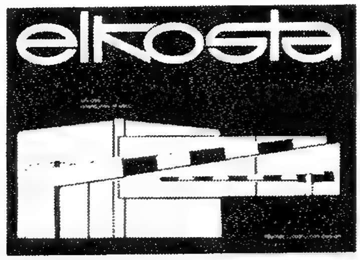
**EUROPEAN OPERATION:**
Delta Scientific Corporation
187 High Street, Tonbridge
Kent, England, TN9 1BX
Telephone: (0732) 366129 / TELEX: 85195151


elkosta®
secures boundaries of sites
Gates, pole barriers, fence construction components, railings, turnstiles, road blocks and special products, galvanized plus plastic coated, long-term protection against corrosion
The site protection with the best resistance
elkosta

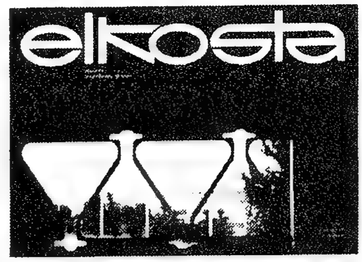
## More information can be provided on our comprehensive product range with detailed catalogues, illustrating the specialist areas of . . .




gates



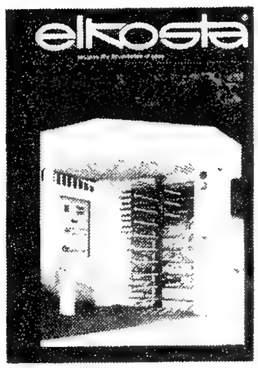

barriers




fence construction components

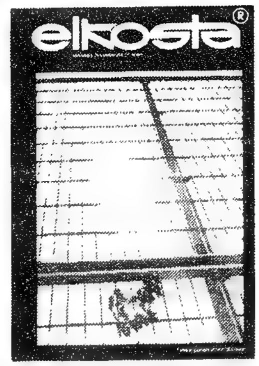
## . . . leaflets on

gates

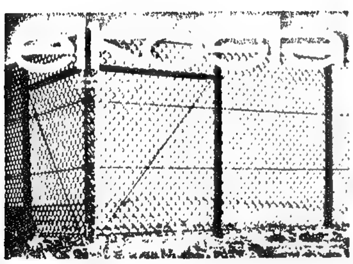



turnstiles


ball·stop·fences



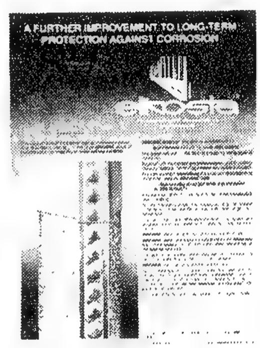

welded mesh fences



fences


palisade fences


road blocks




"Alziplast" post

## . . . as well as elkosta® design specifications as a planning aid and for the preparation of specifications.


design specifications


For information in the U.S. contact:
BARRIERS, INC.
119 South Saint Asaph Street
Alexandria, VA 22314
Telephone (703) 684-0405

03.86/12.0.-A



We constantly work on the development of our products, and we ask for your understanding that we must reserve the right to make alterations regarding the extent of the delivery in shape, equipment, and technical design at any time. No claim for damages can be made from the contents of this brochure with the given details, illustrations and descriptions.

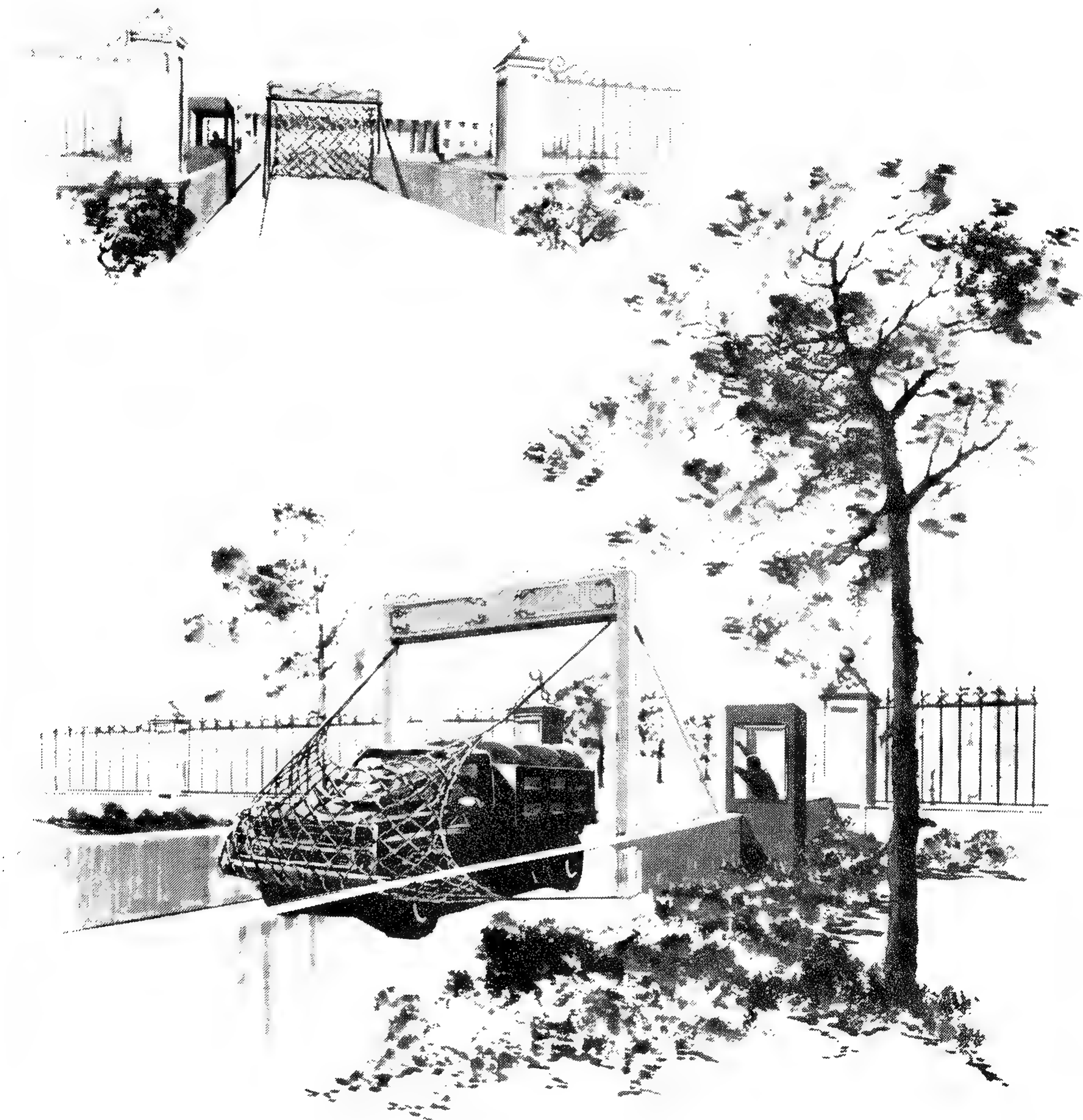
For further information
concerning the

**ELKOSTA product line**

please contact:

**Physical Security Products, Inc.**
117 S. St. Asaph St.
Alexandria, VA 22314

(703) 836-1107



FLEXIBLE BARRICADES, INC.

CRASH PROOF SECURITY GATES

Various features of the gate, not visible here, include:

<u>WIND-UP SHAFT</u> for storage of net in overhead canopy when gate is in "open" position

<u>LIFTING TAPES</u> for raising and lowering the net

<u>POWER DRIVES</u> within canopy and vertical posts

<u>ARRESTING GEAR</u> connected to four corners of net for energy-absorption of impact forces

<u>POWERED CONTROLS</u> manually operated by guard or by-passed to remote control station

<u>KNOTLESS NET'S</u> mesh, corner-sustaining connections for strengthening net and distribution of impact forces

<u>COLOR - GALVANIZING</u> for esthetics to match the surroundings

<u>ARCHITECTURAL IRONWORK</u> for esthetics and camoflage designed as required

* * * * * *

Edw^d. C. Newell

FLEXIBLE BARRICADES, INC.
CRASH-PROOF SECURITY GATES
141 Beacon Street, Boston, MA 02116 367-1010

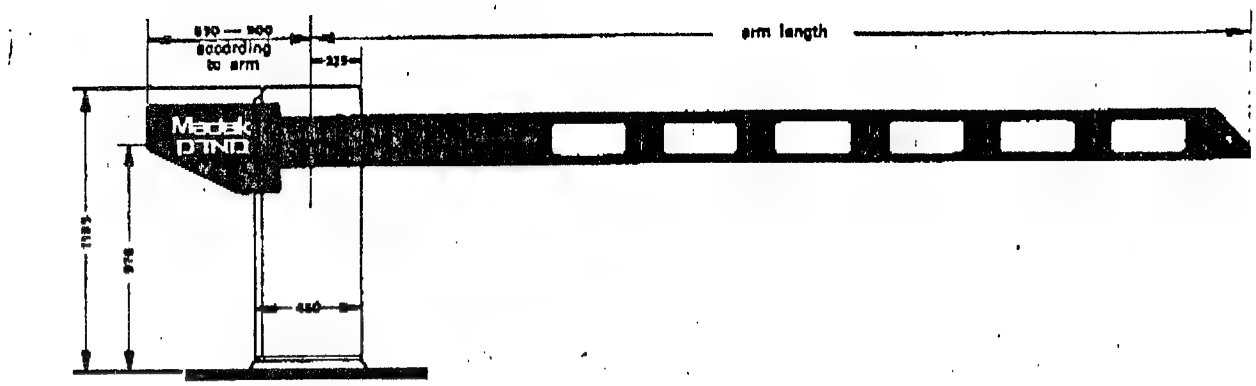
# Madek מאדק

**פתרונות מעולים לפיקוח על התנועה**

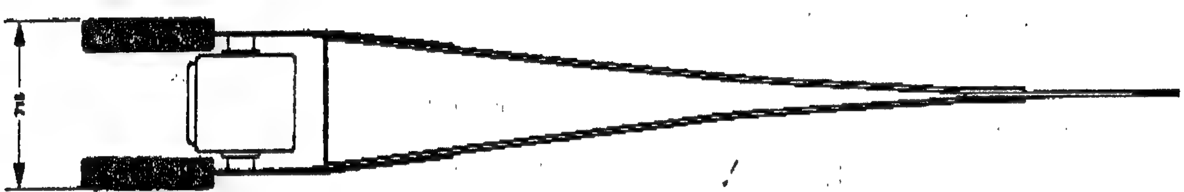
- הפעלה קלה בלחיצת כפתור.
- אפשרות להפעלה ע"י אלחוט ושילובים של מערכות אוטומטיות שונות
- יחידת ההנעה של „מאדק" קבועה ואינה נוסעת עם השער, ולכן מערכות החשמל הן פשוטות.
- השערים מצוידים בסדורים להפעלת חירום ידנית.
- דרישות האחזקה הן מינימליות.
- השערים מעוצבים בצורה מודרנית נאה התורמת למראה השטח כולו.
- ייעוץ ופתרון מקיף לבעיות התנועה והבטחון בשער—ע"י מומחי „מאדק

000989

-6-




General dimensions — side view



General dimensions — Top view

Dimensions are in millimeters.

## SPECIFICATIONS

The esthetically-designed housing of the barrier contains a 3-phase A.C. motor drive unit (standard 400 volts; other voltage optional) with ½ or ¾ horse power capacity. It also contains the barrier control system: transformer, 2 contactors, limit switches for raising and lowering, and complete wiring. The system operates on a low, safe voltage (standard: 42 volts A.C.). Required time for raising barrier arm to an angle of about 80° is 6 seconds. For barriers with arm length of 4 meters or less raising time of 4 seconds is optional.

The drive unit is equipped with a wheel and handle which allow the barrier to be moved manually in case of power failure or any other reason. There are also two specially designed pins which, when removed, free the barrier arm from the drive unit and allow continuous manual operation during an extended duration of power failure.

Standard arm lengths are 3m., 4m., 5m. and 6m. Other lengths, up to 7m., are optional.

The barrier arm consists of two wooden slats. If bumped by a car it will bend but not break; under stronger impact it will snap but will not damage either the car or the housing. The arm can be replaced, easily and inexpensively, by the customer himself.

A flexible steel lattice-net is available for suspension under the arm, to hinder pedestrians from passing under it.

We furnish the customer with full instructions for do-it-yourself assembly and erection, but we shall of course do it for him on request.

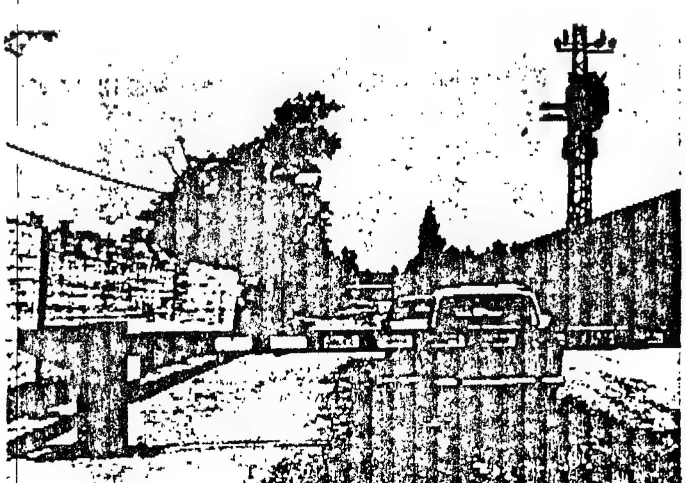
### Other MADEK Gate Equipment

1 Heavier gate barriers, of various degrees of resilience, for withstanding car impact.

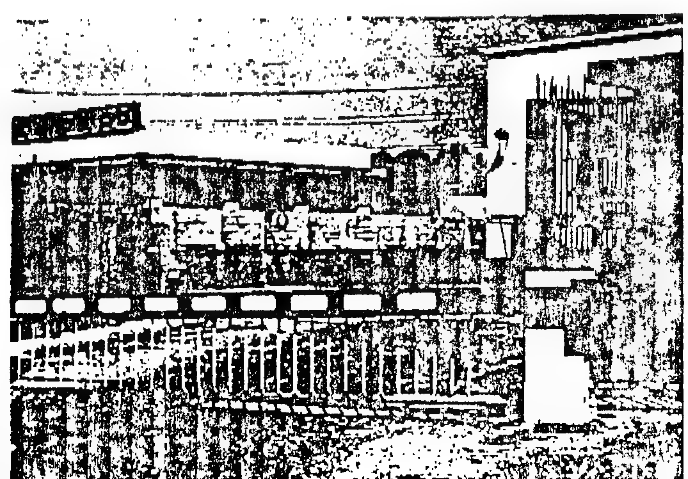
2 Automated systems for parking, payment and control, for parking lots and garages.

3 Swinging and travelling rigid electrical gates of various types.

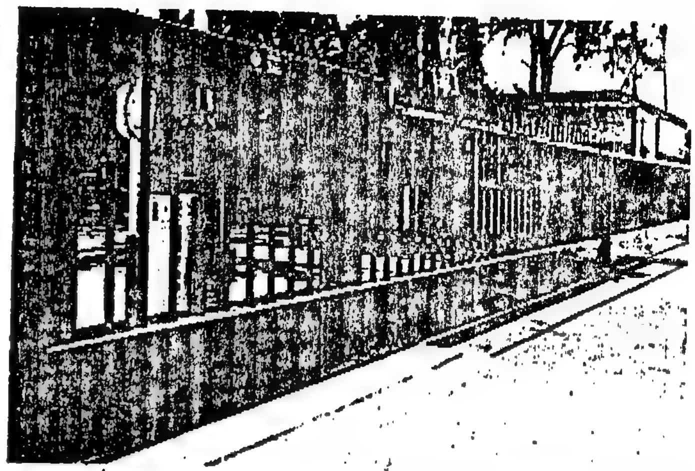
We reserve the right to introduce alterations without notice.



Barrier without lattice-net



Barrier with lattice-net



## שער נע ללא פסים

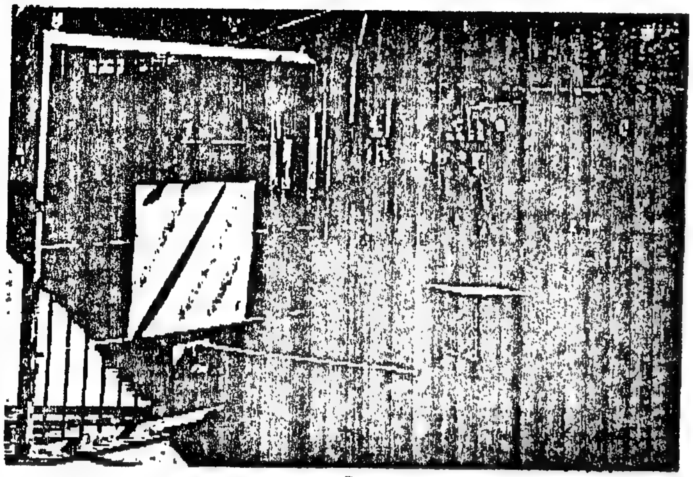
היתרון הגדול של שערים אלה הוא במה שאין בהם, דהיינו, בכך שאינם קשורים לפסים בכביש. לכן אין יכולים להווצר קשיים הנובעים מלקויים באחזקת פסים, ומשקיעת הפסים או הכביש.
שער ללא פסים אפשר להתקין גם במקומות בהם יש שפוע בכביש, או כשהשטח אינו חלק. השער נוסע בצורה חלקה, ובנוי בצורה חזקה ויציבה. שער מרגם זה מתאים לעבודה מאומצת. זמן הפתיחה של השער הוא קצר (מהירות הנסיעה 25 מ' לדקה או 37 מ' לדקה). פתח אפשרי של כנף אחת של שער מסוג זה — עד 8 מ' (16 מ' לשתי כנפיים).

## שער נע עם פס יחיד

בשטח מישורי המאפשר התקנת פסים, וכשהעבודה אינה מאומצת, אפשר להתקין שער נע על פס. אנו מספקים דגם עם פס יחיד בכביש (איננו ממליצים על שערים עם שני פסים, כיון שבעיות האחזקה, והרעידות של השער בתנועתו, גדולות יותר מאשר בביצוע עם פס אחד.) מבנה השער הוא בעל חוזק בינוני. מהירות השער עד 25 מ' לדקה. רוחב הפתח האפשרי לכנף אחת של השער — עד 10 מ' (20 מ' לשתי כנפיים).

## מחסומי זרוע מתרוממים

במקרים רבים אין צורך בחסימה מלאה של הפתח במשך היום, והפיקוח השוטף על התנועה יכול להיעשות ע"י מחסום בעל זרוע מתרוממת בחשמל. מחסומי „מאדק" מסופקים בדגמים אחדים, בעלי זמני פתיחה מ-2.7 ועד 6 שניות, אורכי זרוע עד 7 מ', ובאפשרויות מגוונות לפיקוד ידני ואוטומטי.

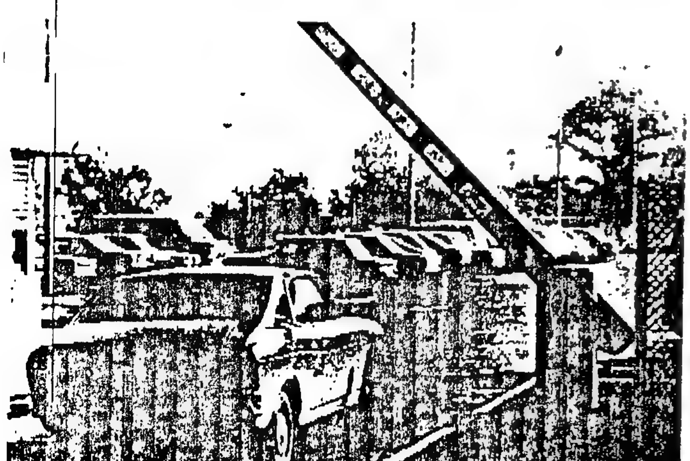


## שער נפתח על צירים

שערי כנפיים על צירים הם לפעמים פתרון נוח, בהתאם לתנאי השטח והמקום. אנו מספקים שערים כאלה, בעלי זמן פתיחה של כ-5 שניות. יחידות ההנעה המשוכללות של „מאדק" מתוכננות כך, שכוחות חיצוניים המופעלים על השער לא יועברו במישרין אל מתקן הסיבוב. וזאת לבטחון ולעמידות יתר.
השערים מסוג זה הם בעלי חוזק בינוני. האורך האפשרי לכנף של שער חשמלי על צירים הוא עד 6 מ' (12 מ' לשתי כנפיים).

## הנעה לשערים על צירים

עבור שערים ידניים קיימים הנפתחים על צירים פותחו יחידות הנעה „מאדק" להנעת השער בחשמל. היחידות משוכללות, קומפקטיות, וכוללות את מערכות החשמל והפיקוד הדרושות. יחידת ההנעה מוצבת בנפרד, ליד השער, ומתחברת אל הכנף שלו בנקודה אחת בלבד. כרגיל אין צורך בשנוי בשער כדי להוסיף אליו את ההנעה של „מאדק".



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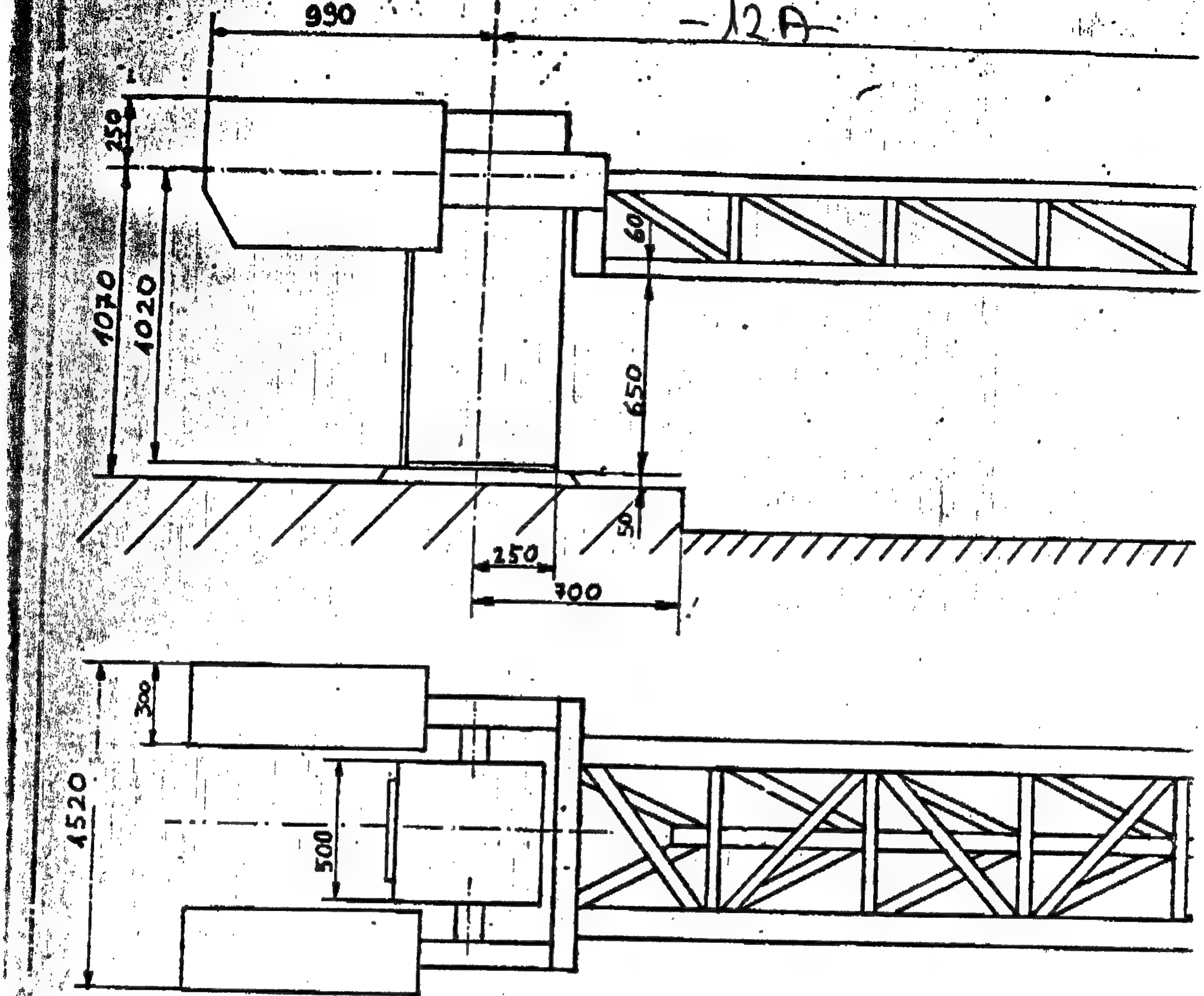


| הערות | מס' שרטוט | מידות גשר | חומר | כמות | תאור | מס' |
|---|---|---|---|---|---|---|
| ~ 1:20 | קנ"מ | מחסום זרוע מתרומם דגם בטחוני כבד | | | | |
| תאריך | חתימה | | | | | |
| שרטט 13.11.83 | | | | | | |
| בדק 20.3.84 | | | | | | |
| אישר | | | | | | |
| מס' השרטוט | | מס' עבודה | ר. גוסינסקי | | | |

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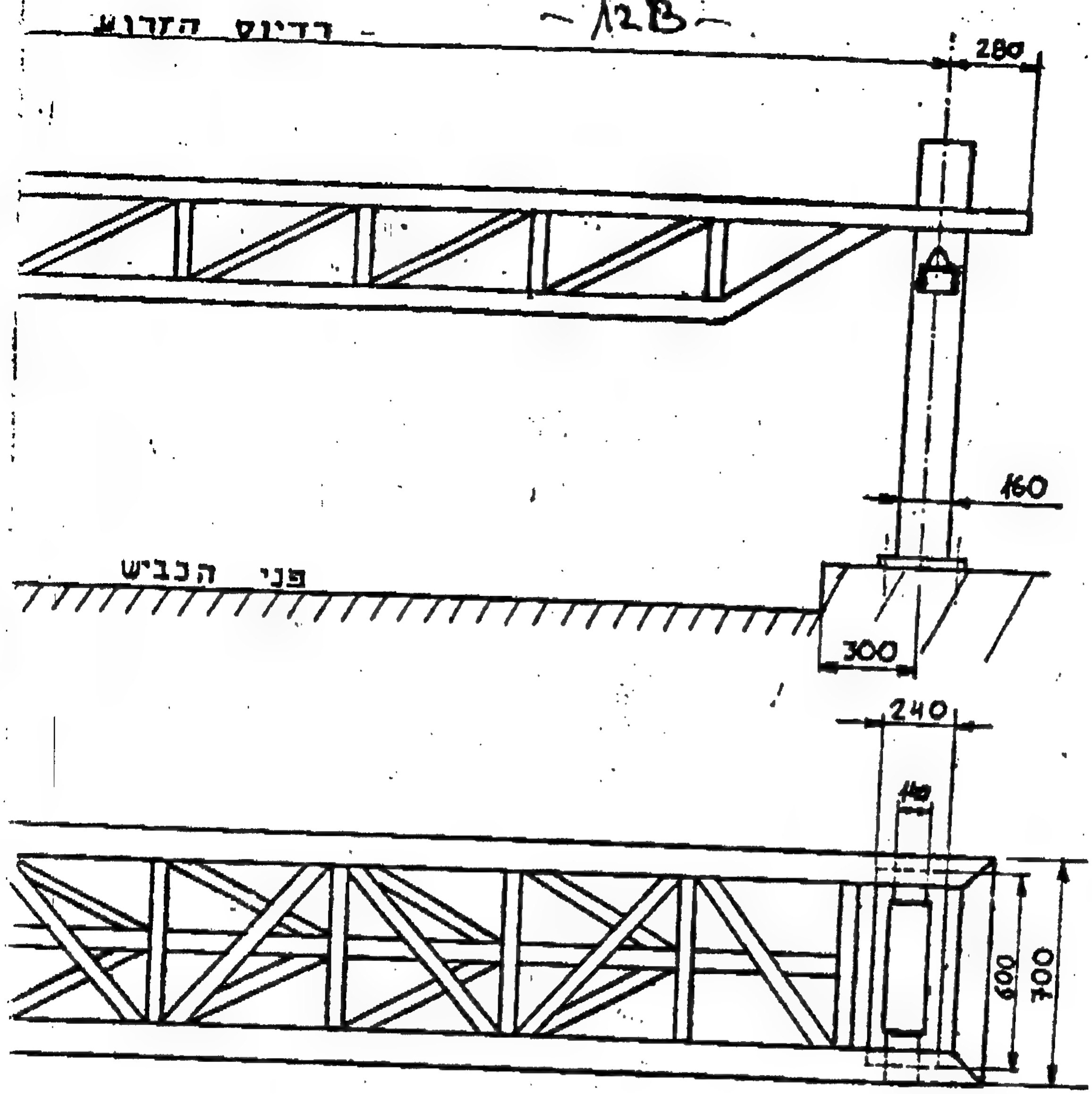
~12B~



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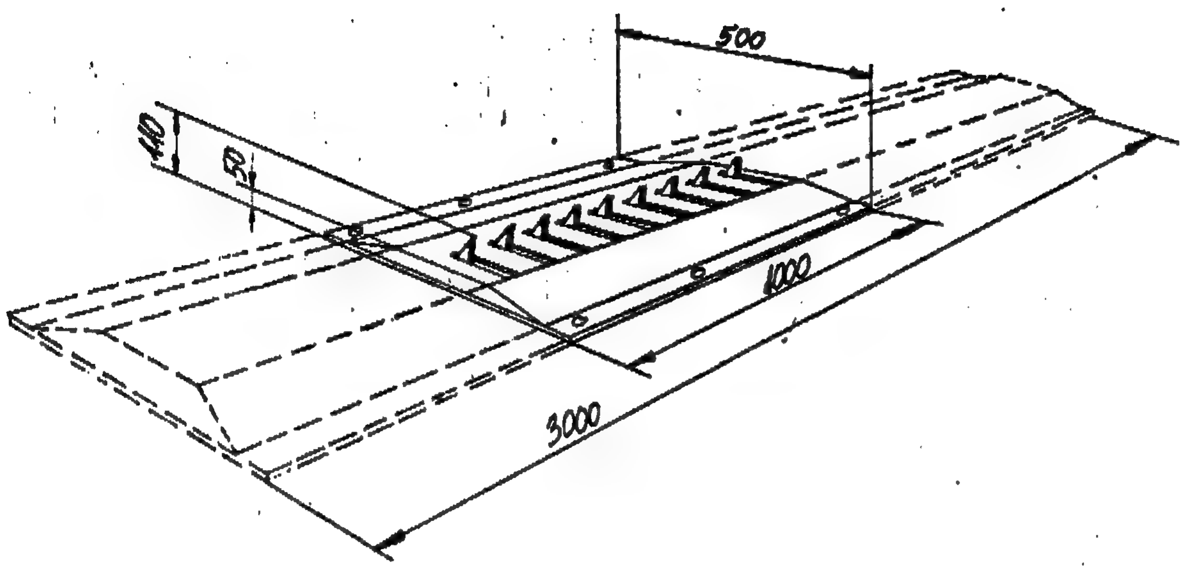
all in mm.




SOLCOOR INCORPORATED
TWO PARK AVENUE
NEW YORK, N. Y. 10016

כל המידות במ"מ

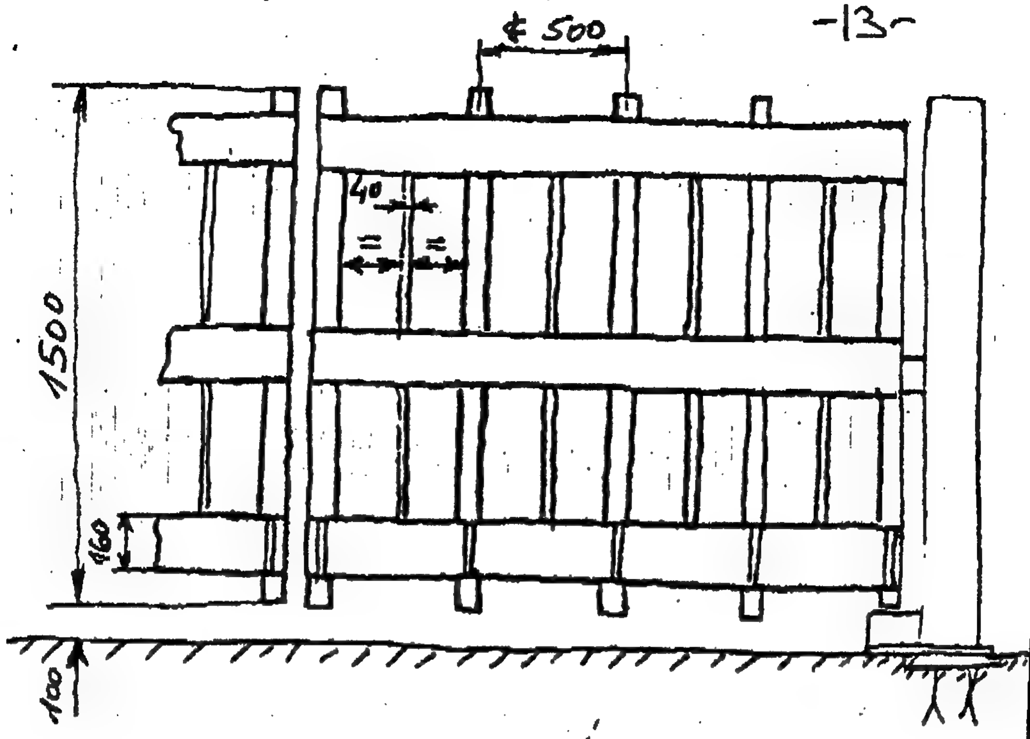
000994

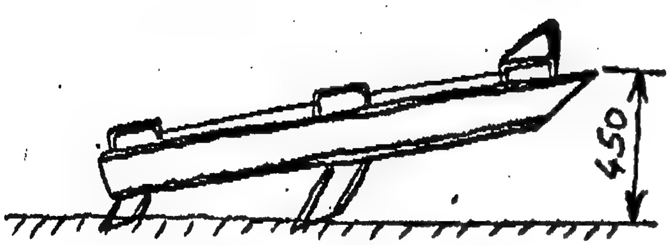
| הערות | מידות נטו | מס' שרטוט | חומר | כמות | תאור | מס' |
|---|---|---|---|---|---|---|
| | | | | | | |

| | תאריך | חתימה |
|---|---|---|
| שרטט | 6.5.85 | גל |

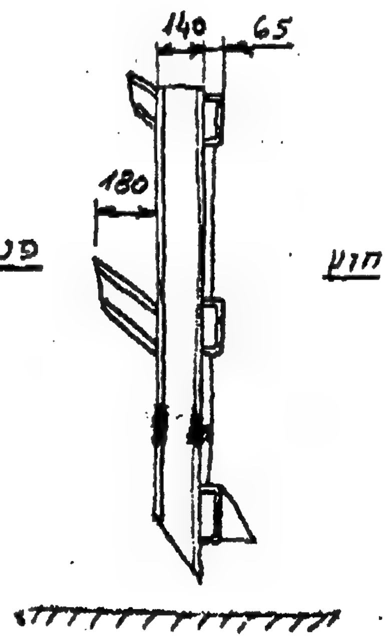
מחסום שינים קפיצי – מראה כללי

הערה המידות עשויים להשתנות!




הכנף במצב הפוך
(לאחר שהופלה)




חתך הכנף



| הערות | מידות נטו | מס' שרטוט | חומר | כמות | תאור | מס' |
|---|---|---|---|---|---|---|

| | תאריך | חתימה | |
|---|---|---|---|
| שרטט | 6.1.84 | | שער ידני על צירים, לחצר דגם בטחוני מתהפך |
| ביקר | | | |
| אישר | | | |

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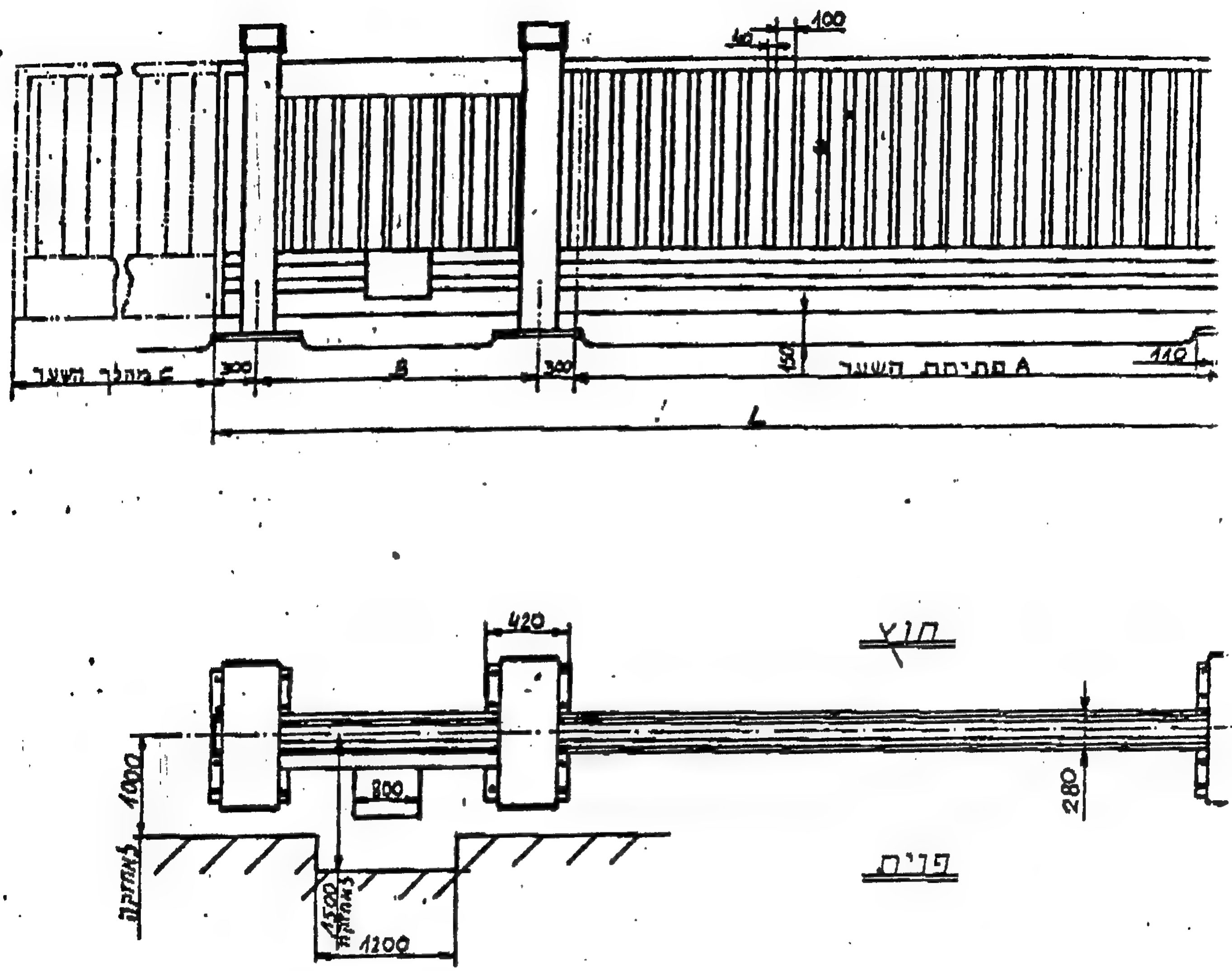


| מס' שרטוט | מידות כשר | חומר | כמות | תאור | מס |
|---|---|---|---|---|---|
| ק.מ. | | | | שער נייד בלי מסילה<br>3.5 עד 12 מ'<br>מבנה בטחוני | |

| | תאריך | חתימה |
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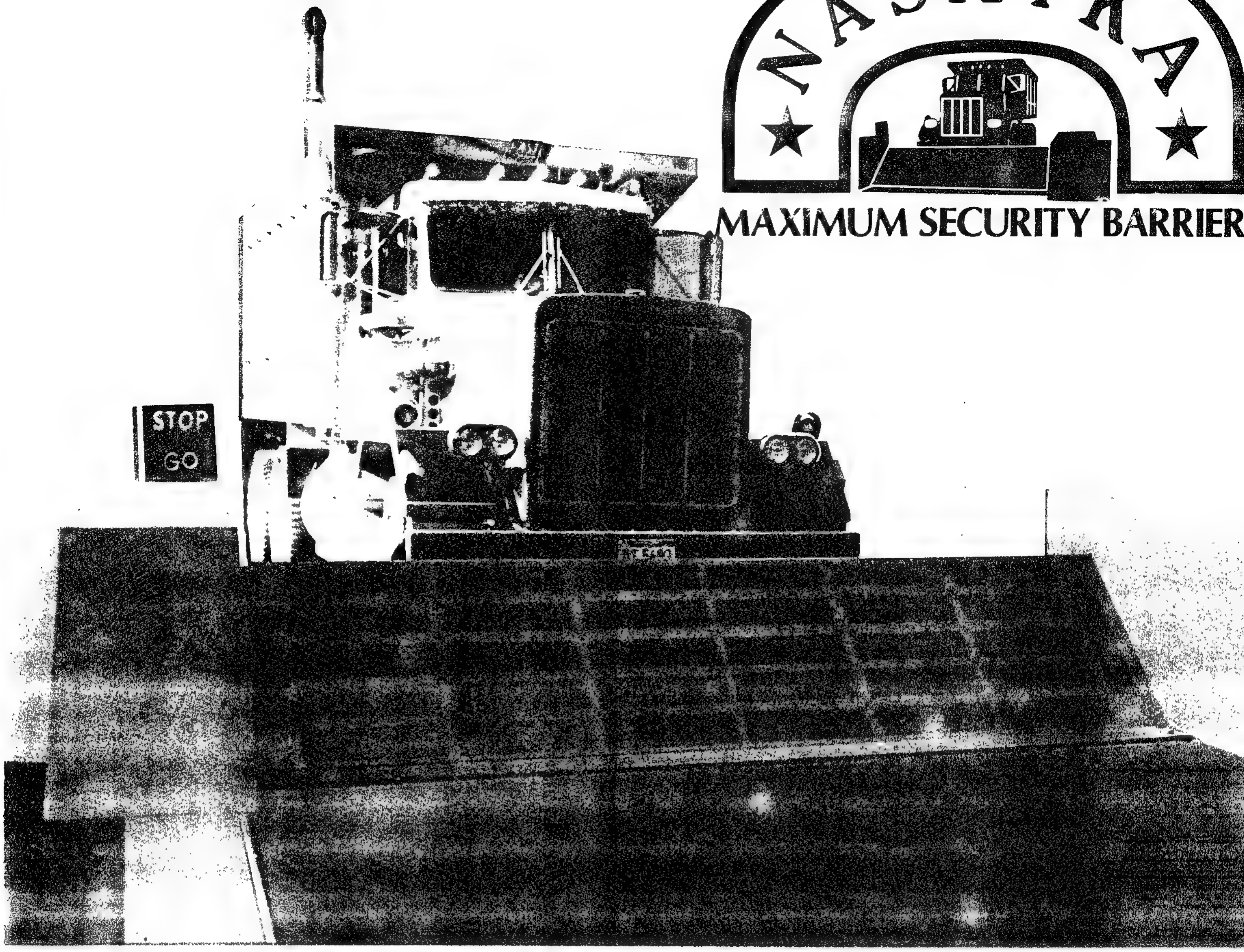
| שרטט | 26.7.84 | [illegible] |
| בדק | | |
| אישר | | |

000996

# NASATKA

## MAXIMUM SECURITY BARRIER




**The NMSB *II* provides effective control of vehicles entering or exiting any facility. The NMSB *II* is designed as a high security access control device for private roads, airports, industrial plants, and as an anti-terrorist device for oil refineries, satellite communications stations, embassies, military bases, and other government installations.**

The **NMSB *II*** series barrier provides the highest degree of security against forced vehicle entry due to its force absorption design coupled with reliable hydraulic power and failsafe electronic controls. The barrier is designed so that the force of impact is absorbed by its large steel base plate and the roadway surface. The **NMSB *II*** hydraulic barrier is able to absorb full vehicle impact at all points of its operational cycle. A system of 1" steel plates and a 2" diameter steel hinge bar ensures that a positive barrier is quickly in place to stop unauthorized vehicles. Since the security of the system is not dependent upon costly excavation, a **NMSB *II*** can be installed is an little as 24 hours on an existing pad and later moved without roadway rebuilding.

The fully electronic programmable controller gives the system a wide range of functions to meet the most demanding application. The **NMSB *II*** can be Guard controlled or operated by use of card readers, digital keypads, laser vehicle identification systems, radio controls, timers with magnetic vehicle detectors, or interfaced with existing security systems. It always provides positive control of the roadway with an important balance between "Safety and Security".

An "Emergency Up" mode of operation will place the barrier in the up position in approximately one-second. In the event of a power failure, a hydraulic accumulator and battery back-up allows the **NMSB *II*** to operate up to 6 full cycles at normal operating speed, with complete electronic control. Additional cycles can be added with the manual hydraulic pump system. Hydraulic power is not required to maintain the barrier in the "Up" position.

Multiple barriers can be controlled from a single hydraulic power system. The system control can be easily programmed to allow alternate action, simultaneous action, or any combination of traffic control.

Operators' design consultants can integrate the **NMSB *II*** with other access control perimeter protection devices to produce a broad range of security system configurations. Our experienced sales, engineering and service departments can provide you with design assistance, training seminars and technical support in perimeter access security systems.

***OPTIONS:***

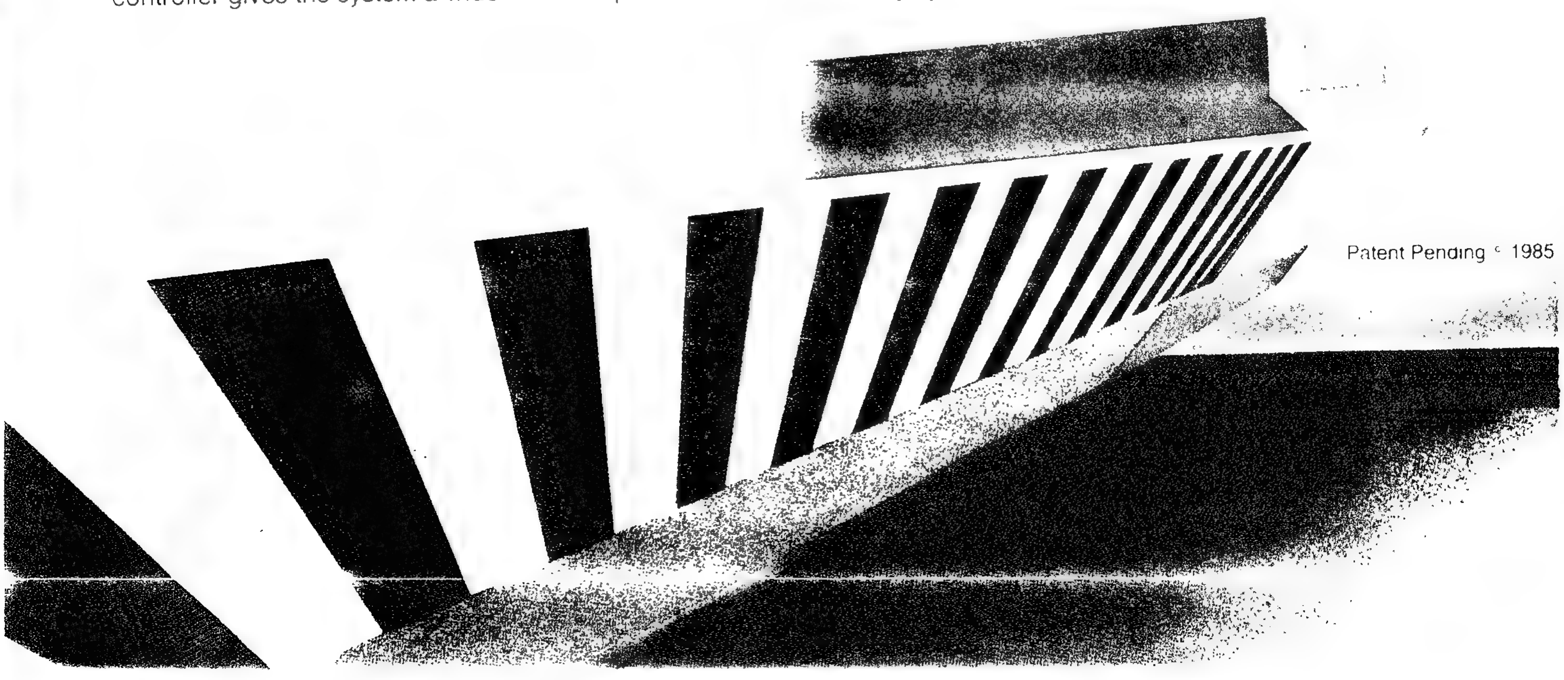
- Manual Hydraulic Pump System (Continuous operation without power)
- Adjustable Cycle Operation Time (4 to 8 seconds)
- Tiger Teeth on Leaded Edge
- Red/Green Traffic Lights and Warning Bells
- Timer/Safety Detector (Returns barrier to up position)
- High Speed Monitor Alarm System
- "Auto-Read Laser" Vehicle Identification System
- Access Control Systems and Closed Circuit T.V.



**Designed & Built (in the U.S.A.) By:**

8405 Dangerfield Place
Clinton, Maryland 20735

**Distributor:**

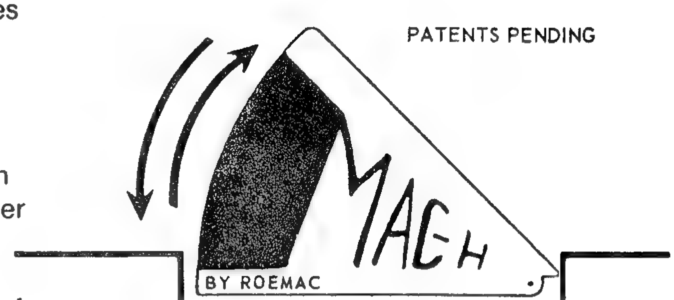


Patent Pending © 1985

# MAC-H
## HEAVY DUTY
## VEHICLE SECURITY BARRIERS

The **MAC-H Vehicle Barrier** is the finest security barrier in the world today. The **MAC-H** combines proven technology with innovative design to produce a barrier capable of stopping heavy, fast moving vehicles as well as providing an effective deterrent to unauthorized entry to restricted areas. The barrier swings into position at the touch of a button to become a solid barrier to traffic.

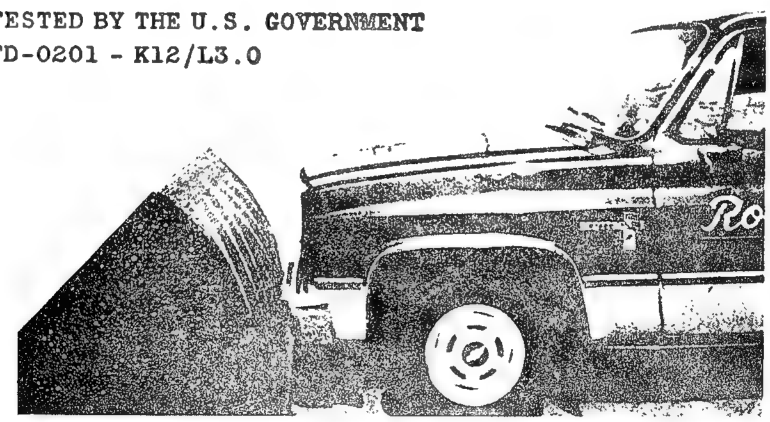
PATENTS PENDING




The **MAC-H** is an aesthetically pleasing means of protecting vital facilities from high speed vehicular terrorist assaults.

The **MAC-H Heavy Duty Vehicle Barrier** is a dependable security device designed for continuous day-in, day-out operation. The barrier is located underground and will allow authorized traffic to pass without obstruction. Upon the need to physically secure the facility, the barrier can be raised to its full 36-inch height in 1.8 seconds to present a formidable obstacle to any approaching vehicle.

**FULLY CRASHED TESTED BY THE U.S. GOVERNMENT**
**MEETS DOS SD-STD-0201 - K12/L3.0**



The **MAC-H Barrier System** has demonstrated, by actual crash tests, its ability to stop a 10-ton truck traveling at 40 miles per hour without suffering hydraulic system damage.

**Ordering Information:**

GSA Contract No. GS-OOF- 87672
FSC Class: 4540

**ROEMAC**
**METAL FABRICATING DIV.**

25 FREDERICKA STREET
NORTH TONAWANDA, N.Y. 14120
PHONE 716/692-7332

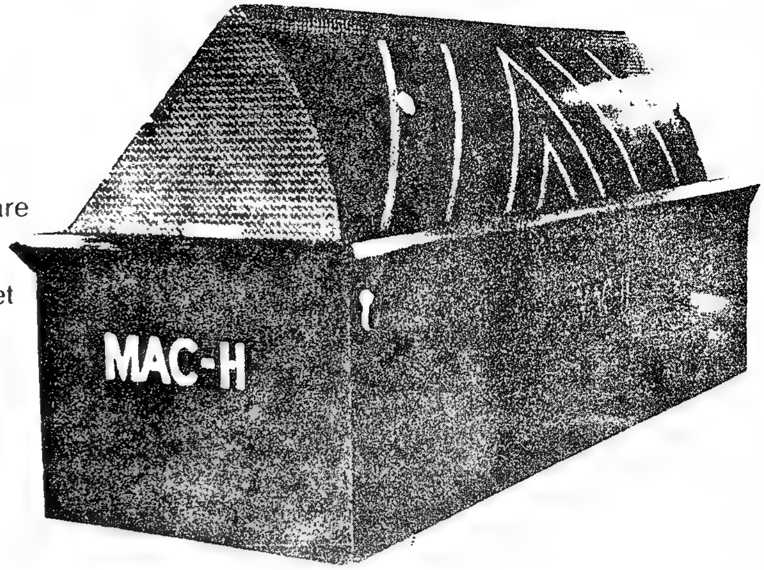
000995

REPRESENTED BY:

Roemac Industrial Sales, Inc.
27 Fredericka Street
North Tonawanda, New York 14120

Each **MAC-H Barrier System** is fully tested and assembled prior to shipment. All components are of the highest quality available.

All barriers are available in widths of from 6 feet to 24 feet, with an optional multiple barrier configuration available.




## Specifications:

**Barrier Height:** All barriers are 36" high above grade when in full up position.

**Barrier Width:** Barriers are available in widths of 6, 8, 10, 12, 16, 20 and 24 feet. Custom width multiple drum systems are available.

**Speed of Lift:** Full down to full up position in under 2 seconds.

**Safety:** The **MAC-H Barrier** is a courteous sentry, designed to do its job without overhangs or pinch points. The top surface is a non-skid diamond plate steel for maximum wear and safety.

**Construction:** Heavy gauge steel plates covering structural steel members that are designed to support the weight of heavy vehicular traffic. All welded construction with no protruding bolts.

## Standard Features on all Barriers:

- Energy absorbing removable barrier drum with patented rotating feature.
- Heavy steel underground holding tank, complete with drain.
- Choice of integral hydraulic system with manual lifting mechanism or remote module located separate from the barrier.
- Electrical panel and push button station ready for connection to your power source.
- Heavy duty high cycle hydraulic cylinders.
- Complete instruction manual including installation, operation and maintenance.

## Optional Equipment:

Hydraulic Oil Heater
Battery Power Backup
Multiple Station Control
Card Access Control
Export Packaging
Hydraulic Oil Cooler
Heated Sump and Pump
Automatic Activation
50 HTZ Motors and Coils
Power Out Hand Pump
Warning Lights
Tamperproof Package
Radio Control Operation
Portability Package


MANUFACTURED BY:

**ROEMAC**
**METAL FABRICATING DIV.**

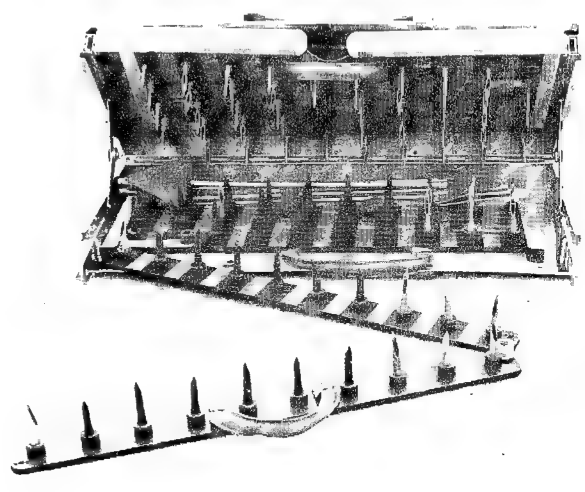
25 FREDERICKA STREET
NORTH TONAWANDA NY 14120
PHONE 716 692-7332


001000

# SHER★HALT

## PORTABLE ROAD SPIKE DEVICE

*SHER★HALT is a portable vehicle-disabling system that's simple, inexpensive and EFFECTIVE. Small enough to fit in any patrol car's trunk, SHER★HALT deploys in seconds. A strip of fifty hollow sharp steel spikes pierce any type of tire, instantly causing deflation. SHER★HALT never wears out, and, when combined with a patrol car, can effectively seal off a 45 ft. wide street. Each road device comes packaged in a carrying case which opens to become a warning sign for stopping traffic. SHER★HALT can also be used as a containment device for sealing off escape routes and keeping suspect vehicles from fleeing. Finally, SHER★HALT requires minimal officer training.*




*Police Products Division*

SHERWOOD

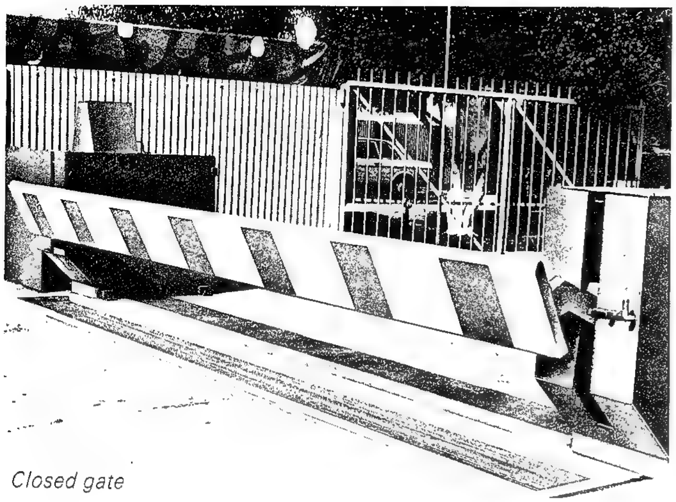
International Export Corporation

**Executive Offices** 18714 Parthenia Street, Northridge, California 91324, USA • Phone: (818) 349-7600 • Telex: 2439, 18-2316, 21-5448

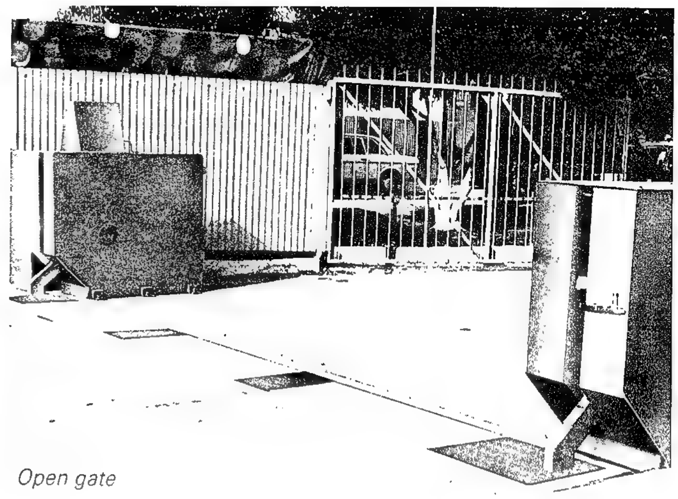
**Branch Office** 2115 Ward Court, N.W., Suite 300, Washington, D.C. 20037, USA • Phone: (202) 293-9350 • Telex: 89-2763, 19-7729

# SHER★GUARD

## POLICE SECURITY GATE

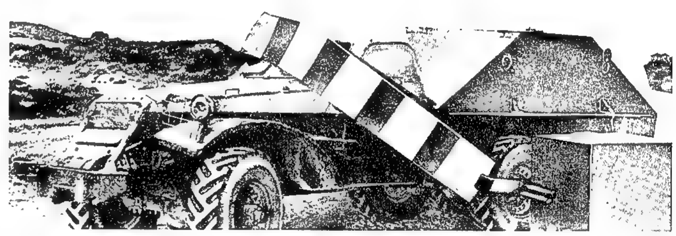


Closed gate



Open gate

How many high-risk facilities fall within your jurisdiction? Embassies? Powerplants? Defense installations? Factories and refineries producing explosive or dangerous materials? Every car that drives by is a potential threat, and there's nothing much a security guard with a service revolver can do when a car comes crashing through a wooden gate or a chain linked fence. Installations which require security demand the ultimate protection from terrorist vehicles—Sherwood's police security gate. SHER★GUARD's simple, reliable construction creates an impenetrable barrier to death-carrying vehicles. Steel cables running through the metal barricade, anchored in two reinforced concrete blocks, will stop even an armored personnel carrier weighing 18,000 lbs. and traveling at 50 mph.



Police Products Division

SHERWOOD

International Export Corporation

**Executive Offices** 18714 Parthenia Street, Northridge, California 91324, USA • Phone: (818) 349-7600 • Telex: 2439, 18-2316, 21-5448

**Branch Office** 2115 Ward Court, N.W., Suite 300, Washington, D.C. 20037, USA • Phone: (202) 293-9350 • Telex: 89-2763, 19-7729

# ATTENTION: VEHICLE BARRIER USER

THE SURVIVABILITY RESOURCE GROUP, INC. HAS DESIGNED A LINE OF PROPRIETARY VEHICLE BARRIERS INCLUDING THE FOLLOWING TYPES:

- FENCE REINFORCING SYSTEM
- VEHICLE PIT
- CONTINUOUS PLANTER
- VEHICLE TURNTABLE
- TAXIWAY CONTROL CORRIDOR BARRIER
- A COMPLETE LINE OF RAPIDLY DEPLOYABLE BARRIERS

ALL OF OUR VEHICLE BARRIER SYSTEMS BOAST THE FOLLOWING FEATURES:

- LOWEST IN-PLACE COST
- HIGHEST RESISTANCE TO PENETRATION
- CAN BE TOTALLY MECHANICAL, REQUIRING NO ELECTRICITY
- HIGHEST RESISTANCE TO SABOTAGE
- SIMPLEST TROUBLE FREE DESIGNS
- LONGEST SERVICE LIFE
- SUPERIOR AESTHETICS
- BUILT IN THE USA

THE SURVIVABILITY RESOURCE GROUP WILL BE PLEASED TO QUOTE A VEHICLE BARRIER SYSTEM FOR YOUR NEXT PROJECT, MEETING YOUR SPECIFFIC REQUIREMENTS.

FOR INFORMATION CALL:

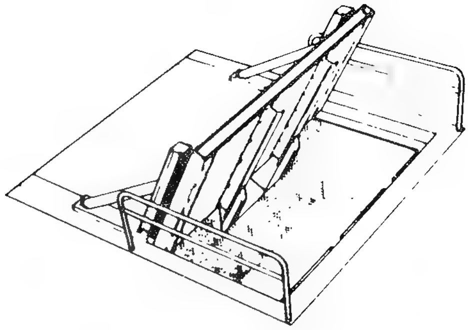
JIM RISHER
GENERAL MANAGER
SURVIVABILITY RESOURCE GROUP, INC.
1960 GALLOWS ROAD
VIENNA, VA 22180
(703) 893-6120


The TRANSTOP Security Gate is a heavy welded steel structure with a 9 foot wide opening. Wider openings are available. The gate is 62'' long and in the BARRIER position, is slanted forward into oncoming traffic. A pit 5' long, 9' wide (or the width of the gate) and 3½' deep is located in front of the gate. The gate is opened forward to form a RAMP covering the pit. Hydraulic or pneumatic power is used to cycle the gate from the BARRIER position to the RAMP position and return. Vehicles enter by driving across the ramp. Backstops are positioned behind the gate on each side and are anchored in reinforced concrete. The backstops are 49'' high and are removable to accommodate wide loads. The Security Gate is available in widths up to 18 feet.

# SECURITY GATE

## DESCRIPTION

The Security Gate consists of a barrier preceded by a pit. At the rear of the pit is a reinforced steel barrier (RAMP) which is slanted forward 40 degrees. The gate is backed up by 6" H-beam stops on each side. 6" rubber dock fenders on each backstop cushion the gate during normal operation and absorb the initial impact if forceable entry is attempted. Guard rails along the sides are available as an option.

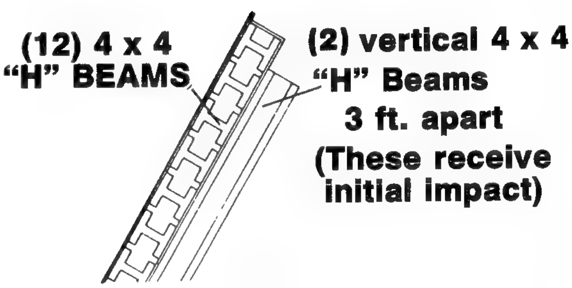


**DESIGN CRITERIA**

- **Stop a 15,000 lb. vehicle traveling at 50 m.p.h.**
- **Reliable**
- **Maintainable**

H-beams mounted vertically on the face of the gate serve to receive the initial impact and to distribute the impact over the beams. The gate is hinged on two 2 1/4" solid steel axles imbedded in reinforced concrete.

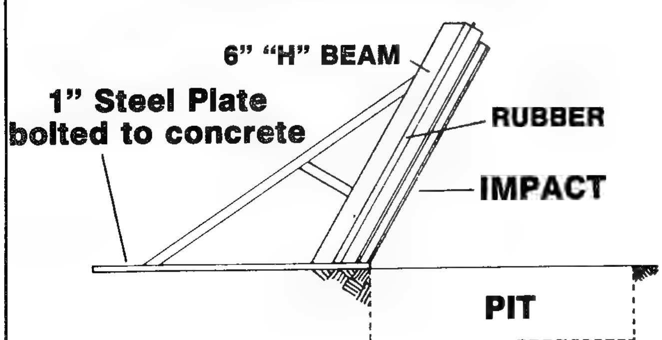
**STRUCTURE OF GATE**




**Gate is covered with 3/16" Diamond Plate both sides**

The gate has been designed and tested to stop a 10,000 lb. vehicle at 50 miles per hour. (Dept. of Defense Standard). A version meeting Department of State requirements of a 15,000 lb. vehicle at 50 miles per hour is also available. The operating systems are designed for reliability. All systems are easily accessible for service and maintenance.

**RESISTANCE TO IMPACT**




The gate is constructed of steel beams sandwiched between steel plates. For the 15,000 lb / 50 mph version, heavier 1-1/4" steel cables attached to the RAMP and anchored in the vehicle pit are also added.

## FAIL SAFE

The TRANSTOP Security Gate may be ordered with the option to be "fail safe" against attack by hostile action. If the gate is in the RAMP position, it may be cycled to the BARRIER position in less than 1 second to deny vehicle passage. Should the operating system fail or be damaged, the counterweight will automatically raise the gate to the BARRIER position. An hydraulic or pneumatic system is used to cycle the gate. The gate is held in the RAMP (down) position by hydraulic or pneumatic pressure. If pressure is lost for any reason, the gate will be overbalanced by the counterweight and immediately rotate to the BARRIER (up) position.

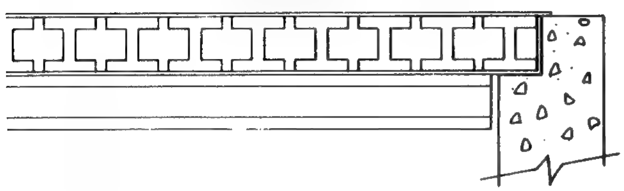
The gate is backed up by a 6" H-beam on each side. The backstops are bolted to a reinforced concrete foundation and one or both backstops may be removed to provide access for wide loads.

The TRANSTOP Security Gate can accommodate vehicles of any width by removing one or both backstops. The standard gate measures 9 feet between backstops, but gates may be ordered in widths up to 18 feet for special applications.

# VERSATILE

## EXTRA WIDE LOADS CAN BE ACCOMMODATED

**Unbolt and remove one or both of the impact posts.**

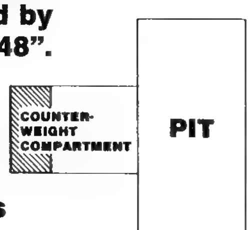


## EASILY MAINTAINED

Maintenance is minimal. One grease fitting on each of the two main bearings makes it easy to lubricate from the roadway. The bearings are sealed to prevent foreign matter from entering. The hydraulic/pneumatic and electrical systems can be serviced by removing a 20" x 48" plate from the road surface behind the gate. A sump pump is provided in the conterweight pit to remove rain water. All operating systems are well protected from sabotage, yet can be easily accessed for service or maintenance.

# MAINTAINABILITY

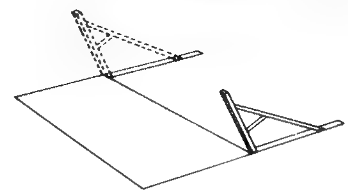
- **Entrance to counterweight compartment is covered by removable plate, 20" x 48".**
- **Operating system is exposed when cover is removed.**
- **An area 20"x 24" allows entrance into compartment to service sump pump.**




# OPERATES IN ADVERSE WEATHER

**Frozen snow and ice will not impair operation of gate**

**Diamond plate extends over gap**



The Security Gate is designed to operate in all types of weather. An overhanging lip prevents foreign matter from building up between the ramp and the pit. The sump pump will prevent water from accumulating in the pit. Heating elements can be built into the pit when the geographical area dictates.

# RELIABILITY

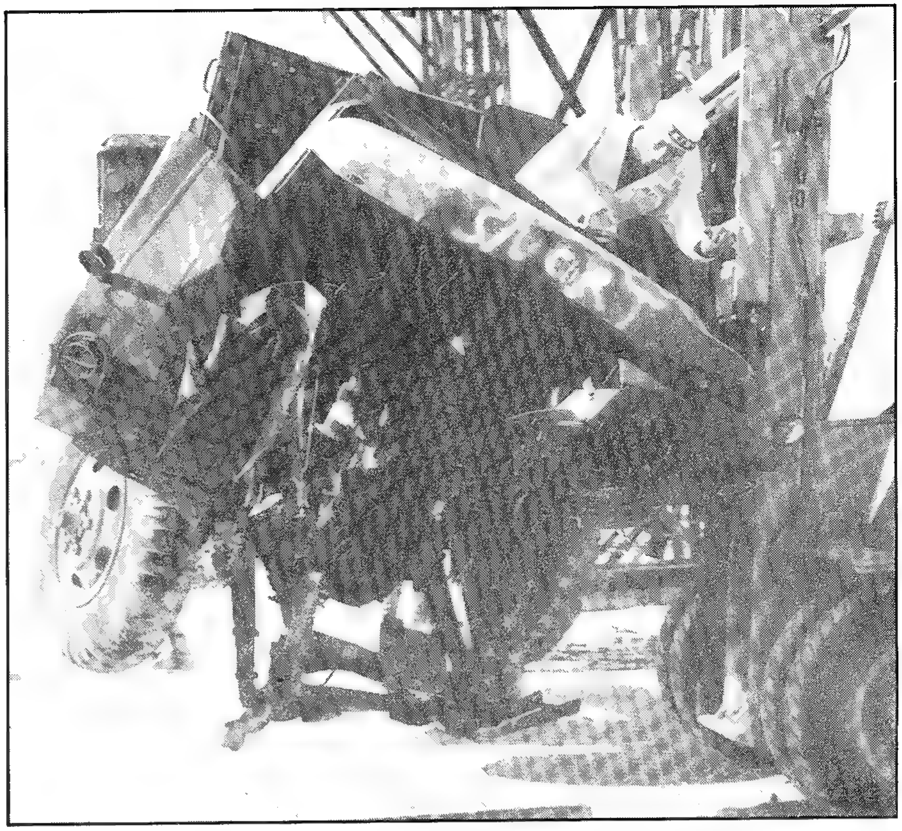
- **Operating system operates at well below rated capacity.**
- **Counterweight will close gate should operating system fail.**

Reliability is designed into the TRANSTOP Security Gate. The hydraulic or pneumatic system operates well below their rated capacity. A continuous duty, industrial quality electric motor is used to power either system. The system will operate on 110 or 220 volts A/C, 50 or 60 cycles, as specified. If the powered operating system should fail, the counterweight will bring the gate to the BARRIER position. A manually powered hydraulic system is also available for remote sites.

The system is designed to be easily maintainable in all aspects. All operating systems are located in the counterweight compartment and are accessed through a removable 20"x 48" steel plate. The sump pump is recessed in the floor of the pit and all other equipment is raised 12" above floor level.

The Security Gate may be operated in either of two modes: normally open (RAMP) or normally closed (BARRIER). Modes may be switched at any time. As an example, the gate may be positioned in the RAMP position during peak traffic periods and then positioned to the BARRIER position during light traffic periods and operated on a one vehicle per cycle basis. If the situation dictates, the policy may be to maintain the gate in the BARRIER position at all times, and open it only for one vehicle at a time. The Security Gate is designed to be compatible with either mode or any combination.

In areas where electrical power is not available, a manual system is available to open the gate. The counterweight will close the gate very rapidly.



## MEETS GOVERNMENT REQUIREMENTS

This gate has been tested by the Navy at the Naval Weapons Center, China Lake, California. It stopped and destroyed a 10,000 lb. truck (6 x 6) impacting at over 50 miles per hour.

EASY TO INSTALL. The TRANSTOP Security Gate is provided with an installation kit which contains all necessary materials for installation. JUST ADD CONCRETE! All rebar is cut to length and pre-fabricated. Parts are numbered and color-coded for ease of assembly. Simple assembly is all that is required, no welding. Complete installation instructions are included with each kit. Field representatives are available to supervise the installation.

For information on cost and availability, or if you have any questions, please contact Carl Damon at (714) 540-3241.

**TRANSTOP CORP.**

2010-D South Eastwood Street, Santa Ana, California 92705

714/540-3241

For release at the
"Securing Installations Against Car-Bomb Attack"
Technical Conference
Washington, D.C.
May 15, 16, 17, 1986

## INTRODUCING THE USS/IBC HIGHWAY BARRIER SYSTEM

## IN PERIMETER SECURITY APPLICATIONS

The IBC Mk-7 barrier is a proven high-performance highway barrier system (Figure 1) which has a number of characteristics useful in the protection of facilities against car-bomb type attack.

The IBC barrier is a series of modular steel bins assembled end-to-end in a continuous chain then filled with a dense ballast material. (See Figure 2.) The combination of mass and mechanical strength provides full impact performance even though the system is not anchored to the ground. The IBC Mk-7 barrier has been extensively impact tested, and after more than 2-1/2 years of use on major highways has been subjected to more than 300 impacts without failure. At least one tractor trailer struck the installation on Interstate 95, in Broward County, Florida, and was redirected without penetration or overturning.

The IBC barrier is portable; 900' of the system can be carried on a standard 40" flatbed trailer. It can be assembled at a rate of 1 mile per day with a 20 man crew, and without any heavy equipment. It rests on the ground; it requires no posts or foundations. It can be removed just as rapidly as it was assembled.

The IBC barrier is open at the bottom, and the lid is optional, so the barrier is built right around obstacles without slowing the assembly process (Figure 3). The height and width of the barrier can be varied as needed using standard components. Thus it can be installed virtually anywhere, handling trees, fire hydrants, etc., with ease.

IBC barrier can be stored in a tiny area because the components nest so tightly. (See Figure 4 - Each bundle is 10" in height.) It can be reused many times over. Pallets could even be air dropped to remote sites.

Because it is in essence a 44" wide x 42" high steel box filled with sand or earth or another locally available dense fill material, it would be effective at containing small arms fire without ricochet. The large volume of sand contained within such a relatively "soft" structure could provide significant absorption of the energy of a nearby explosion.

IBC barrier is modular and very rapidly repaired without heavy equipment.

The IBC barrier is removable. If all security measures now contemplated are implemented in concrete, the occurrence of peace in any of the present "hot spots" would leave fortresses which would be very costly to remove. Because the IBC barrier is not fixed to the ground, upon removal the site is left in exactly its original condition.

The barrier can be manufactured virtually any place where steel sheet and a press brake are available; it need not be shipped from the U.S.

USS/IBC HIGHWAY BARRIER SYSTEM

Contact: UNITED STATES STEEL CORP.
Phone: 412/433-3987
600 Grant St.-Room 1844
Pittsburgh, PA 15230

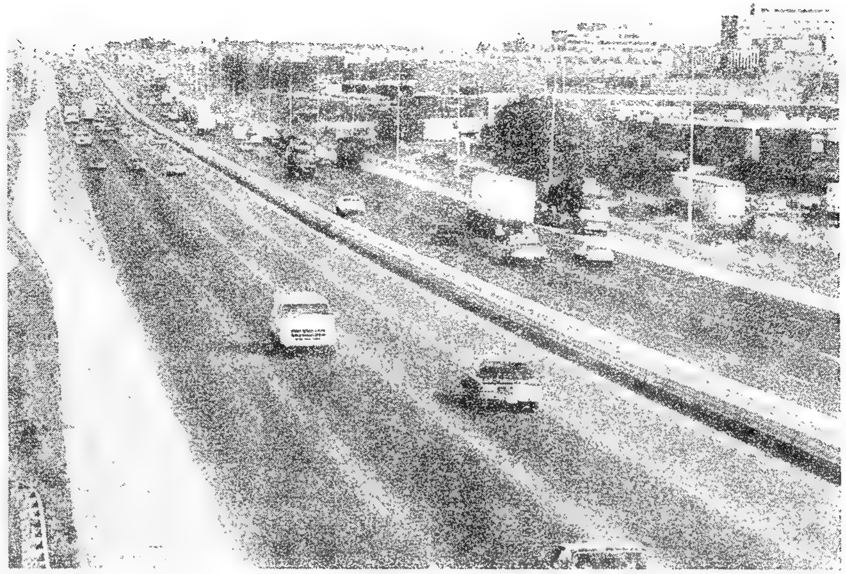
INTERNATIONAL BARRIER CORP.
Phone: 416/863-6344
33 Jarvis Street
Toronto, Ontario M5E 1N3

** Note attached photographs and drawing **

RFS24:j

5/12/86

USS/IBC HIGHWAY BARRIER



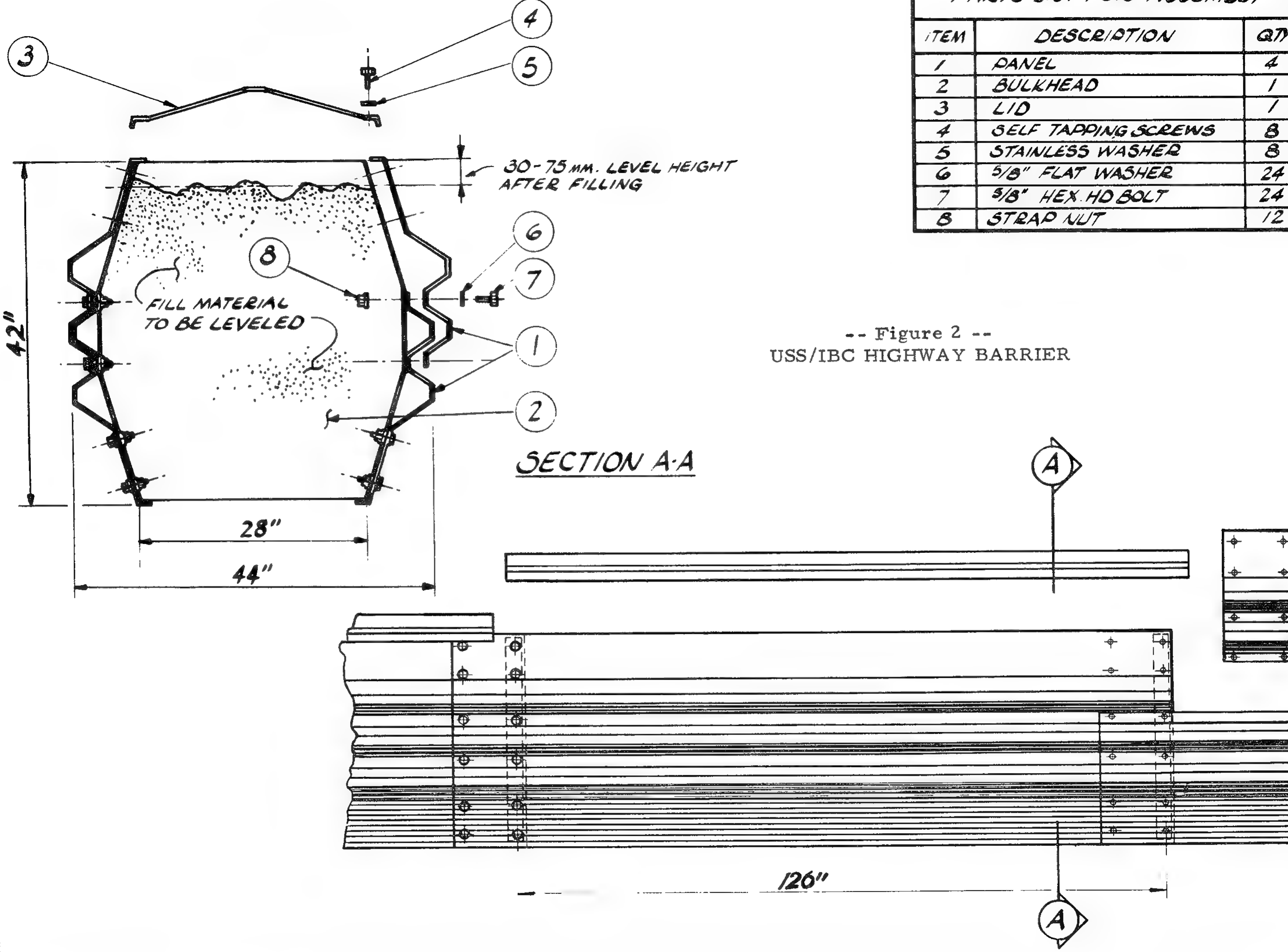
USS/IBC HIGHWAY BARRIER

-- Figure 1 --

-- Figure 3 --

-- Figure 4 --

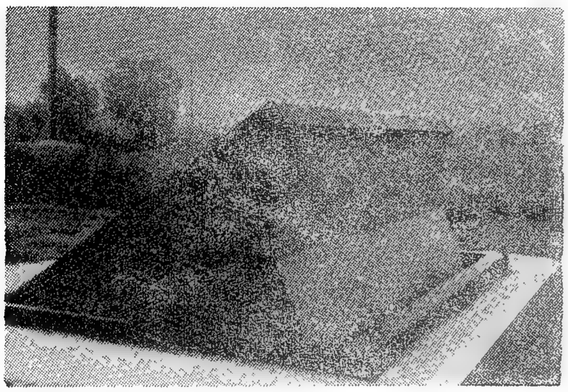
| PARTS LIST FOR ASSEMBLY | | |
|---|---|---|
| ITEM | DESCRIPTION | QTY |
| 1 | PANEL | 4 |
| 2 | BULKHEAD | 1 |
| 3 | LID | 1 |
| 4 | SELF TAPPING SCREWS | 8 |
| 5 | STAINLESS WASHER | 8 |
| 6 | 5/8" FLAT WASHER | 24 |
| 7 | 5/8" HEX. HD BOLT | 24 |
| 8 | STRAP NUT | 12 |

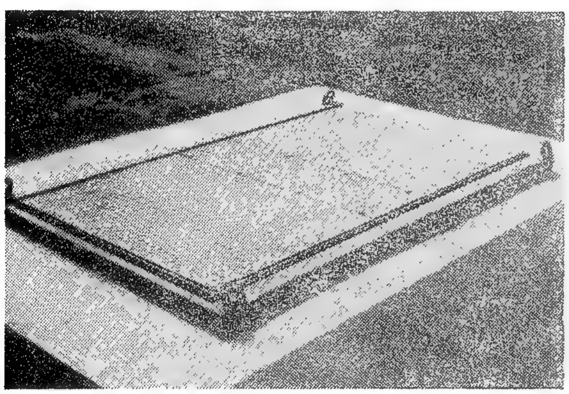



-- Figure 2 --
USS/IBC HIGHWAY BARRIER

Western Industries, Inc.

# Magnum series Vehicle Arrest System





Lifting hooks removed for permanent installation.

15,000 GVW - 50 MPH

The MAGNUM series vehicle arrest system provides the ultimate in asset protection. Developed specifically for high risk - high speed impact this unit allows architectural flexibility, esthetic quality and maximum survivability. Whether the front gate driveway of a major governmental installation or rear gate of a seldom used facility a MAGNUM series vehicle arrest system offers reliability and practicality with serviceability.

Available in a wide variety of widths, power combinations and operating speeds, the MAGNUM series can deliver whatever the application requires. Western Industries, Inc. has for nearly 20 years accommodated virtually dozens of custom applications. Needs varying from 72" to 144" widths are easily supplied from our large inventories. In many instances multiple units become the easiest alternative. Operating characteristics can provide for fast action, automatic control or even manual control. Control systems including remote master panels, guard house panels, annunciators, indicator lights and master switches or simple one button panels or hand operated pumps are all part of the wide variety of MAGNUM series operating equipment.

Two major advantages of the MAGNUM series vehicle arrest system are ease of installation and low maintenance requirements. Fabricated to simply be set in place and concrete poured around the barrier, the MAGNUM unit allows high impact absorption yet easy replacement post-impact. Maintainability, always a major factor in determining true ownership cost, is "built-in" from day one. Access to all components through either the top deck or front face plate allows quick service and less traffic interruption. Corrosion resisting anodes can be provided for longer equipment life even in moisture intensive environments. Performance, quality, safety . . . hallmarks for nearly two decades.

CALL ON US FOR A WIDE VARIETY OF SECURITY EQUIPMENT.

GSA-SCHEDULE - Contract No. GS-00F-79519

## GENERAL SPECIFICATIONS-MAGNUM series

Effective Widths:
72″ to 144″

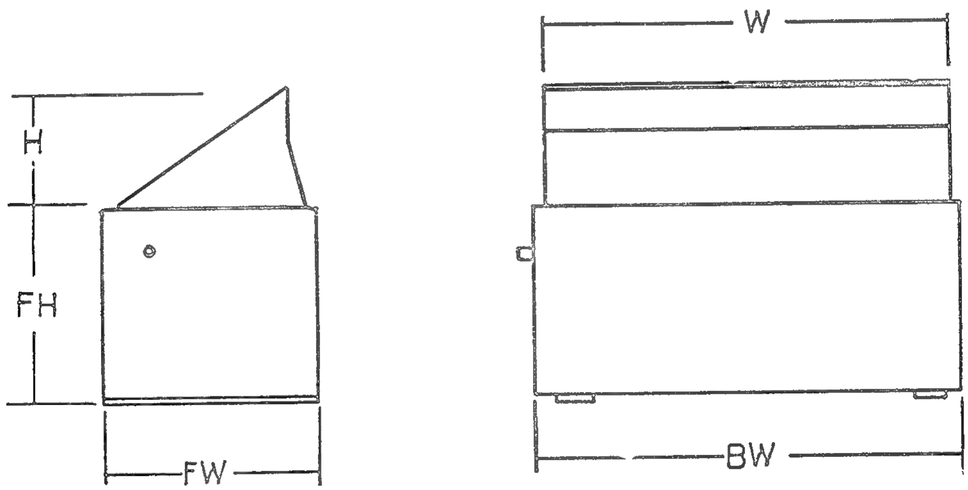
Standard Height:
32″

Operating Characteristic:
Hydraulic cylinder in combination with scissor linkage to maintain lift in the event of a hydraulic power failure.

System Electrical Requirements:
Control units can be made available in most configurations-single or three phase, 50 or 60 hertz, gas engined powered, hand pump with the actual controls built into the unit or more preferably as a stand alone system. A wide variety of control panel configurations are available.

Water and moisture removal:
Aggregate of sufficient porosity should be installed beneath the unit prior to setting unit in place. Gravity should be utilized to aid drainage. A submersible pump can be provided.

Environmental Concerns:
Electrical heaters can be provided where operating conditions require. Special metal coatings and colors available.



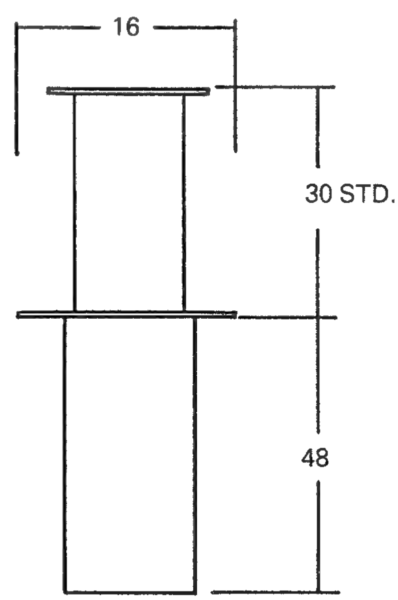

H -- Height 32″
FH -- Frame Height 45″
FW -- Frame Width 62″
W -- Width 72″ to 144″
BW -- Base Width 79″ to 149″

**Western Industries, Inc.**
Manufacturing and Developmental Services
1405 Sinclair Street
Bottineau, North Dakota 58318
(701) 228-3757
TELEX 29-6001 IMS-FGO

Western Industries, Inc.

# Super-B Bollard Vehicle Arrest System

The Western Industries model Super-B Bollard vehicle arrest system provides low cost - low maintenance physical security for a wide variety of applications. Available manually or hydraulically operated the Super-B maintains a high degree of security while still being "environmentally subtle". The Super-B is constructed of extra heavy steel tubing, available in varying heights, standard color black, can be supplied in any color or galvanized, is easy to install and particularly suited to wide - open spaces requiring a high level of security. The standard up - height is 30 inches. Gravity should be utilized to enhance drainage; submersible pumps and heater strips available.




CALL ON US FOR A WIDE VARIETY OF SECURITY EQUIPMENT.

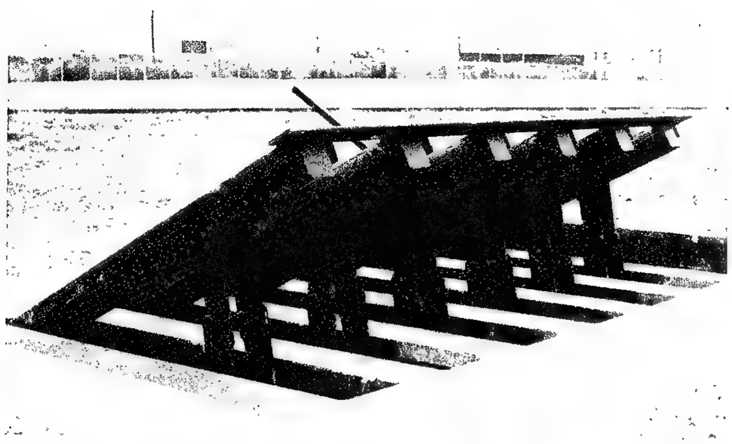
GSA-SCHEDULE - Contract No. GS-00F-79519

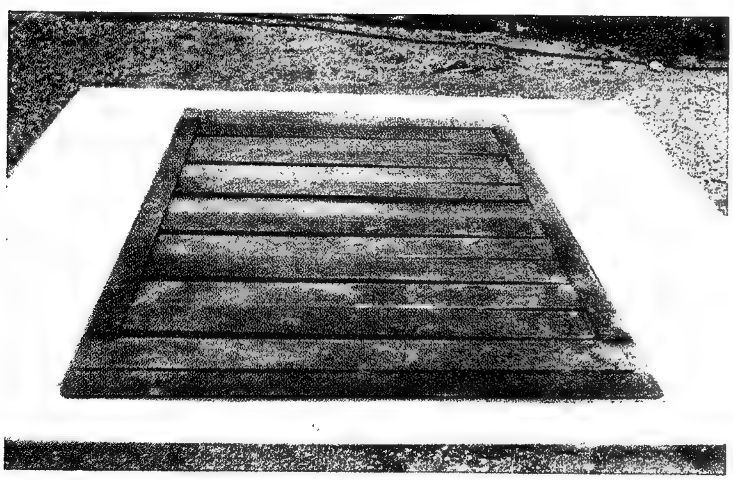
**Western Industries, Inc.**
Manufacturing and Developmental Services
1405 Sinclair Street
Bottineau, North Dakota 58318
(701) 228-3757
TELEX 29-6001 IMS-FGO

# Portapungi

*"The Brand That Stands"*

## VEHICLE ARREST SYSTEMS





**THE PORTAPUNGI VEHICLE BARRIER** is specifically designed to inhibit motorized bicycles, off-road vehicles and trucks from entering any secured zone or compound. This unit, while almost unnoticeable, provides superior protection for people and facilities, can be delivered on a worldwide basis quickly and can be installed, usually, in a matter of hours.

Quality manufactured products have been the company's hallmark since 1970. Engineered and produced to withstand hot dry sandy conditions, wet boggy humid conditions, or frozen polar environments, the unit continuously performs to original standards even after hundreds of thousands of crossings.

Construction consists of an electrically welded steel tubing subframe utilizing 4″ square crossmembers on 17″ centers and 4″ steel longitudinal stringers. Integral with the subframe is a 1¾″ solid steel trunnion shaft. It is on this trunnion shaft that the 4″ square prongs are rotated. Deep penetration of the oncoming vehicle may, literally, remove the front axle of the vehicle upon impact.

All tubular materials meet or exceed ASTM Grade A500B (58,000 min psi Tensile; 46,000 min psi Yield).

As standard equipment, the unit is operable with a manual lever. The actuation time can be virtually instantaneous.

As optional equipment the unit is available hydraulically operated. Actuation time is less than 2 seconds per half cycle. The effectiveness of the unit may not be diminished if the unit has completed less than total actuation. For additional operating effectiveness the unit is constructed with no bolts or hardware that can be removed to reduce the operational characteristics of the unit.

The unit can be locked manually in the up or down position.

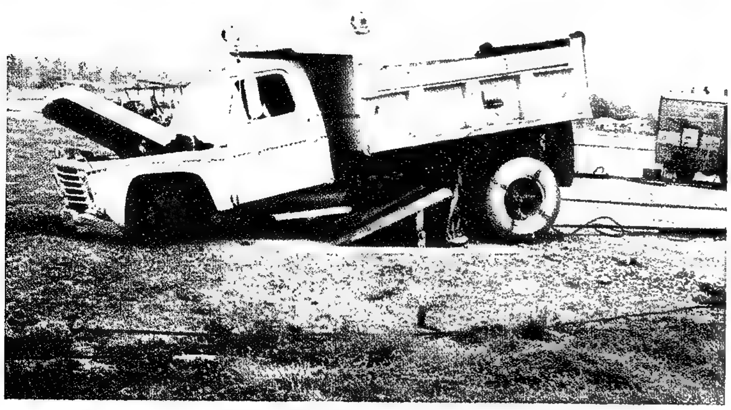
Due to the simple and straight forward design, the unit can be installed in a number of ways. Anchoring the unit may be accomplished by either:

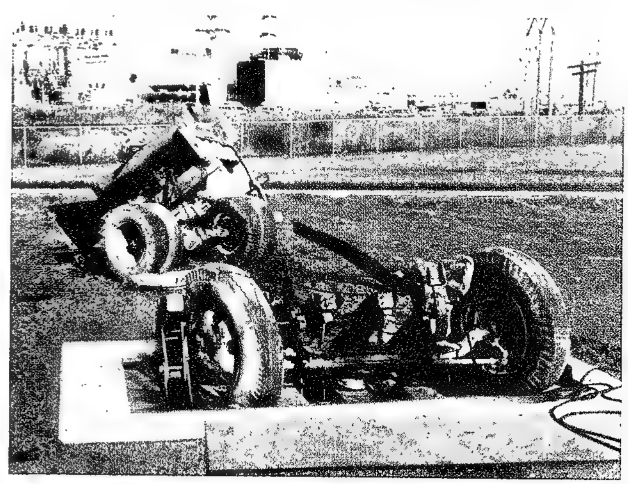
a) using the provided anchor screws. This method allows installation of the unit literally in a matter of minutes — anywhere. Equipment and personnel requirements: Methods of lifting and placing unit in desired position. Two men are required for insertion of anchor screws.

b) by installing the unit as a more permanent part of the street, road or thoroughfare. This can be easily accomplished by "digging in" the unit. While not only being unnoticeable it also remains level with the surrounding road surface grade and thus no "bump" is seen — or felt — when crossing the unit.

The units are fabricated to allow connection end to end.

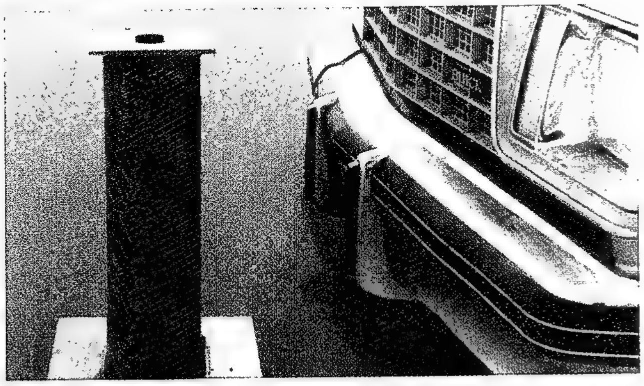
Portapungi Vehicle Barriers are the industry's standard in heavy duty vehicle arrest systems. Most models are in stock and ready for immediate shipment.



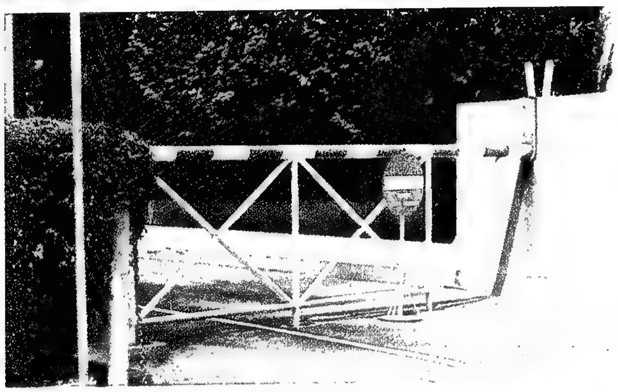


## PERFORMANCE PROVEN. . .TIME TESTED

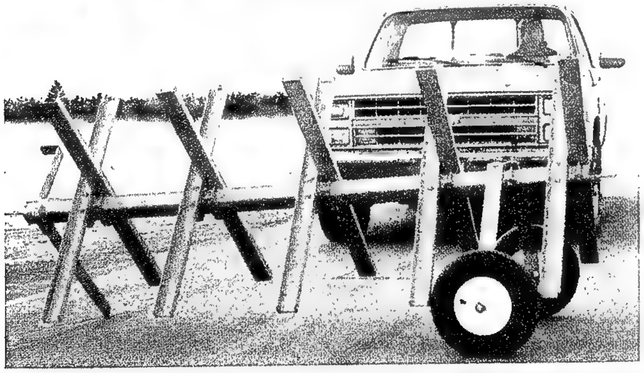
# EQUIPMENT FOR EVERY APPLICATION



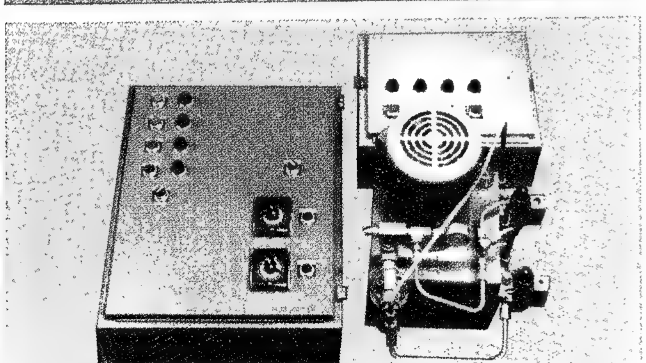
**PORTAPUNGI BOLLARD:** The Portapungi Bollard delivers high level perimeter security while maintaining a relatively subtle profile. Manufactured of high strength, large dimension structural steel, the unit is easily installed in all environments. While maintaining a height of 24″ in the up position, the unit retracts to only ½″ above surface grade level. The Portapungi Bollard is available as a manually operated unit or can be equipped with a Portapungi Power Unit for fast and easy automatic control. Standard Color: Bright Orange Enamel.



**PORTAPUNGI SEMAPHORE:** The Portapungi Semaphore allows superior protection at a reduced investment. Manufactured of extra heavy steel tubing, laced internally with steel cable, the unit locks into an exclusive Portapungi hold down assembly. Installation in any climate can be accomplished in only hours. The unit is also available with an expanded metal mesh lower section for greater pedestrian control. The Portapungi Semaphore is available for either manual operation or equipped with the Portapungi Power Unit for automatic control. Standard Colors: Red and White.



**PORTAPUNGI ROLLOUT:** The Portapungi Rollout offers fast, convenient, effective and very inexpensive protection. Designed to be completely mobile, the Portapungi Rollout can be deployed in a matter of minutes. For traffic or crowd control this system is a must. Manufactured of lightweight, high strength components, the units are easily assembled and will provide many years of lasting service. The Portapungi Rollouts are available in 8′, 10′, or 12′ lengths, can be hooked together end to end as well as be towed at speeds up to 12 miles per hour. Standard Color: Bright Orange Enamel.



**PORTAPUNGI POWER UNITS:** The Portapungi Power Unit provides automatic control for the Barrier, Bollard and Semaphore equipment. Wherever operational needs require actuation at a distance from the Barrier, Bollard or Semaphore, the Power Unit can provide reliable and safe service. Equipped with a stand alone hydraulic pump, the unit comes with a remote mast control panel with system power switch, adjustable time buzzer to indicate excessive "non-secure" position and position indicator lights. Additionally, the standard package includes a guard house control panel with indicator lights. Standard Voltage: 220 V. Single Phase.

## G.S.A. CONTRACT NUMBER GS-00F-79519

Western Manufacturing Co., Inc. • 1405 Sinclair Street S. • Bottineau, ND 58318 • 701/228-3757



Quality. . . . .Since 1970

DESIGN OF SYSTEMS ARCHITURE

TO RESIST THE CAR-BOMB THREAT

# PHYSICAL COUNTERMEASURES
# FOR THE PROTECTION OF BUILDINGS
# AGAINST "CAR-BOMB" ATTACK

by Eve Hinman, Research Engineer
Weidlinger Associates

## I. INTRODUCTION

The protection of civilian facilities against terrorist attack is a new and evolving art, derived from modern military technology. The protection of a building or a structure in which a facility is housed is called "hardening". This military term implies protection against all weapons effects, including blast, temperature, secondary fragments, etc. In order to harden a structure effectively, the following series of distinct disciplines are used:

- o threat assessment
- o weapons effects
- o risk analysis
- o structural response analysis
- o systems design

This classical list is used in the design of hardened military systems. With important modifications, this list is also applicable to civilian facilities, which are subject to attack by terrorists using conventional weapons (RPG, machine guns, etc.) and unconventional weapons, such as "car bombs".

Weidlinger Associates has become familiar with the weapons

effects of the "car bombs" by designing military structures subject to nuclear and conventional weapons and have learned to modify this knowledge to deal with terrorist warfare. This paper is partially-based on work performed for the Foreign Buildings Office of the Department of State during the course of developing engineering guidelines for hardening our embassies abroad.

## II. THREATS AND COUNTERMEASURES

The "car bomb" is only one of the threats which must be contended with. For civilian structures such threats may be classified as shown in Figure 1. At the present time the most devastating explosive threat is the "car bomb". Generally, if the facility is hardened against this threat, it should be able to withstand (with minor additions) many of the other threats shown in Figure 1.

Presently, the "car bomb" is the major threat, however, we must recognize that as we succeed in protecting ourselves, the nature of threats will change. This is the classical case of the evolution of "defense responsive" attack scenarios. There is even a sort of fashion in terrorist attack modalities as the sobering statistics [1] shown in Figure 2 indicate.

Hardening is not the only one way to protect a building. To put hardening into context, various kinds of countermeasures must be considered:

| | COUNTERMEASURES: |
|---|---|
| | o Political action |
| General | o Military action |
| | o Police action |

***

Specific
- o Intelligence
- o Keepout
- o Hardening

Although the first group listed above as general countermeasures is crucial, we, as individuals, have little control over these aspects of counterterrorism, and they will not be discussed here. We do have control over the second group of specific measures, and the degree to which these are implemented determines the overall degree of protection.

It is important to recognize that this list is ordered by level of effectiveness. In this context:

HARDENING IS THE LAST RESORT

when

- o Deterrence
- o Prevention
- o Preemption

have failed.

Hardening is not a cure-all, it is not even the most effective countermeasure. For example, last year at least 90 planned attacks against US citizens were foiled by effective police and intelligence action[2]. Therefore, hardening must be considered in the context of all other specific countermeasures. Furthermore, it must be emphasized that safety lies only at the intersection of these three sets of countermeasures, as they are shown in Figure 3.

It is useful to classify countermeasures in terms of those that require human intervention, called active countermeasures:

**ACTIVE COUNTERMEASURES**

- INTELLIGENCE
- GUARDS
- SENSORS
- SEARCH
- SURVEILLANCE
- ACTIVE DEFENSE
- ACCESS CONTROL
- RESCUE

Those that do not require but facilitate human intervention are called passive countermeasures (See Figure 4).

In addition to the hardening of the building, we note from Figure 4 that the passive measures include the physical protection of the perimeter and access points and also the functional and physical planning of the building and the grounds. Some of these ideas are illustrated schematically in Figure 5.

## III. WEAPONS EFFECTS

We now turn our attention to the effects of the explosion produced by a "car bomb". An explosion may be defined as a very rapid chemical reaction that releases energy at a very high rate, characterized by an audible blast. The energy of the explosion is coupled into the air and the ground, and some of it

is manifested by thermal radiation.

A more practical view is to classify such effects by the damage mechanism (see Figure 6). The principal damage mechanism is the air blast, which is manifested by a spherical (or hemispherical)shock wave that contains highly compressed air (ambient overpressure). This shock wave produces an external pressure affecting the exterior walls, caving in windows, and finally, the entire structure. The shock front expands with a very high velocity, and as it encounters a wall surface, it reflects and amplifies the intensity of the pressure. The rapid motion of the air also creates a wind of very high velocity (dynamic pressure), which, in turn, generates secondary projectiles. The part of the energy coupled into the ground, creates ground displacements and accelerations similar to a very high-intensity, but short-duration earthquake.

The air blast is quantified by a series of parameters, which are a function of the attack scenario (see Figure 7). Once the blast has been quantified, the air blast parameters (Figure 8) are determined (see Reference 3).

Because of the complicated nature of the airblast phenomena, it is customary to characterize the air blast by the peak ambient overpressure, $P_o$, which is a function of the Yield, W, (i.e. the quantity of the explosive material measured in equivalent pounds of TNT) and the range, R, (i.e. the distance of the explosion). $P_o$, is proportional to $W/R^3$ and may be taken as an index of the potential damage caused by the explosion. For some targets, the impulse of this

by the explosion. For some targets, the impulse of this pressure turns out to be the relevant measure. A plot of $P_o$ versus R is shown for two values of W in figure 9.

The most important characteristics of the curves shown in Figure 9 are:

(1) The peak overpressure decays very rapidly with increasing range; e.g. if the range is doubled, the pressure is rapidly reduced to 13% of its value.

(2) The pressures, even at a great distance, may be very large; e.g. a 2 Ton blast, produces a peak pressure at 100 feet that is more than 20 times that of the pressure produced by a hurricane wind. The same effect exists at 50 feet from a charge 1/8 as large (500 lbs.)

The examples shown in this figure are for two weapons which are probably representatiave of medium and large "car bombs" (although the explosive yield of the car attack at the US Marine barracks has been judged to be even larger). The smaller of the yields shown (500 lbs.) corresponds to the yield of one of our general purpose aerial bombs, the MK83. The most important and obvious conclusion is to be as far as possible from the explosion. This advice is even more urgent if we consider the effect of the explosion on people. The mechanisms that cause injury are:

- o Collapse of the building
- o Flying fragments
- o Airblast

As we will see later, hardening can generally offer safety against the first of these risks, i.e. it can prevent collapse. If there are window and door openings, one will not be able to prevent the penetration of the air blast into the interior, which in turn will produce projectiles, causing injury to occupants. Furthermore, air blast itself can kill or injure. At pressure levels of 50 psi (assuming high impulse content), there are no survivors, and the threshold for damage to the human lung is approximately 10 psi [4] (see Figure 10).

## IV. RISK ANALYSIS - OPTIMIZATION:

We must clarify the objectives of hardening because the effectiveness of hardening is measured by the degree to which the objectives are achieved at a given cost. Depending on the purpose of the facilities, hardening is aimed at one or more of the following objectives:

### OBJECTIVES OF HARDENING:

To Prevent:

- Loss of life and injury
- Loss of function
- Loss of contents

These objectives are somewhat different from those set for hardened military targets, where the overriding purpose is to preserve the mission (i.e. to launch a strike, or to command, communicate, etc.) Such military targets are designed in terms of the value of the target, such as "exchange ratio" and "aim point costs". These are used in cost trade-off studies to determine the optimal structure for a given cost and set of

design constraints.

The objectives for hardening of civilian targets are different. One important trade-off is in terms of the cost of hardening versus the cost of additional land required to provide a stand-off distance beyond a secured perimeter ("keep-out"). An example of such a trade off study is shown in Figure 11.

In this figure it is shown that for a particular W, the cost of increasing the stand-off distance, R, between the building and the protected perimeter increases as the square of R. The cost of hardening is related to the inverse cube of R (consistent with the ratio $W/R^3$). The total cost of protection for a given yield is the sum of the cost of hardening and the cost of additional land. Note that the curves shown are notional; the actual costs vary with specific sites and design constraints.

The maximum effective range is where the inherent resistance of the building is sufficient to resist the blast without hardening; in which case the cost of hardening is zero, and the total cost of protection is the additional cost of land only. The optimal range is where the total cost of land and hardening is a minimum.

A family of such curves is plotted for each threat of interest, and a minimum-cost curve is plotted by connecting all the minimum cost points, corresponding to various yields.

A similar procedure is used to determine the optimal level of protection by obtaining the minimum cost of the attack as a sum of the minimum cost of protection (as determined previously) and the cost of potential loss of damaged contents or disabled

sum of the minimum cost of protection (as determined previously) and the cost of potential loss of damaged contents or disabled functions (see Figure 12).

This analysis is applicable to a storage facility (e.g. a garage, warehouse) or to a building containing equipment (e.g. transformers, transmitters, utilities).

In principle this type of analysis could be used for facilities housing people, provided it is permissible to assign a value to lives lost. Society frequently does assign such values. For instance, courts assess damages for bodily injury or loss of life; governments legislate protective measures against natural disasters. The cost of of upgrading the seizmic resistance of building is estimated at 22 million dollars per life saved; and, in the transportation sector, cost benefit studies estimate the cost per life saved at about $300,000 [5].

Thus far, the probability of a given level of attack has not been considered. When meaningful statistics are available, such as for earthquakes or windstorms, risk analysis techniques may be used. Risk in this context is defined as the probability of regreting a decision made; in our case, regarding the protection level assigned. The objective of risk analysis is to arrive at a system which will minimize the probability of regrets (see Figure 13).

In the case of counter-terrorist strategy, the risk is not quantifiable by this methodology, and risk analysis techniques used in protective design for military targets are not applicable. This is due to an important difference between terrorism and more conventional forms of warfare. In military

applications it may be assumed that the attack is rational, in the sense that the cost of the attack is commensurate with the value of the target, and that the enemy has a finite number of weapons. Such assumptions are not valid in our case.

In developing a policy for the protection of US Embassies, we have not set a finite value for human life, instead we used afortiori arguments to define an achievable level of protection. These arguments and the design constraints are summarized in Figures 14 and 15.

## V. RESPONSE ANALYSIS/DESIGN

The optimization process described must be performed for a number of candidate designs. From these studies an optimal concept is selected. A detailed, dynamic response analysis is then performed using this concept. The overall sequence of designing a hardened facility is outlined in Figure 16.

An example of such a process is given in Figure 17. In this example, a series of candidate designs were considered, and the optimal design was chosen on the basis of cost considerations in terms of the depth of burial of the facility.

The response analysis considers the effect of the explosion on various components of the structure, and also on the structure as a whole, as shown in Figure 18. The response analysis requires the inputs shown in Figure 19.

Analytical/numerical techniques that are used in dynamic response are shown in Figure 20 in order of increasing complexity. The choice of the procedure depends on the complexity of the structure.

If a degree of standardization of the structural components feasible and the geometry of the building is not too complex, the analysis and design is accomplished in one step by means of design charts, such as shown in Figure 21 from the Engineering Guidelines for New Office Buildings[6]. Use of such charts must satisfy requirements shown in Figures 22 and 23.

A more time-consuming procedure uses a simplified calculation, where the relevant response of the structure and its individual components may be obtained by analyzing a single degree of freedom (SDOF) model: i.e. a mass on a spring and a damper as shown in Figure 24 [7].

Finally, if the structure is quite complex or more precise calculations are justified, an experimentally verified material model, with a finite element continuum code, such as TRANAL [8], is used, as shown in the example in Figure 25.

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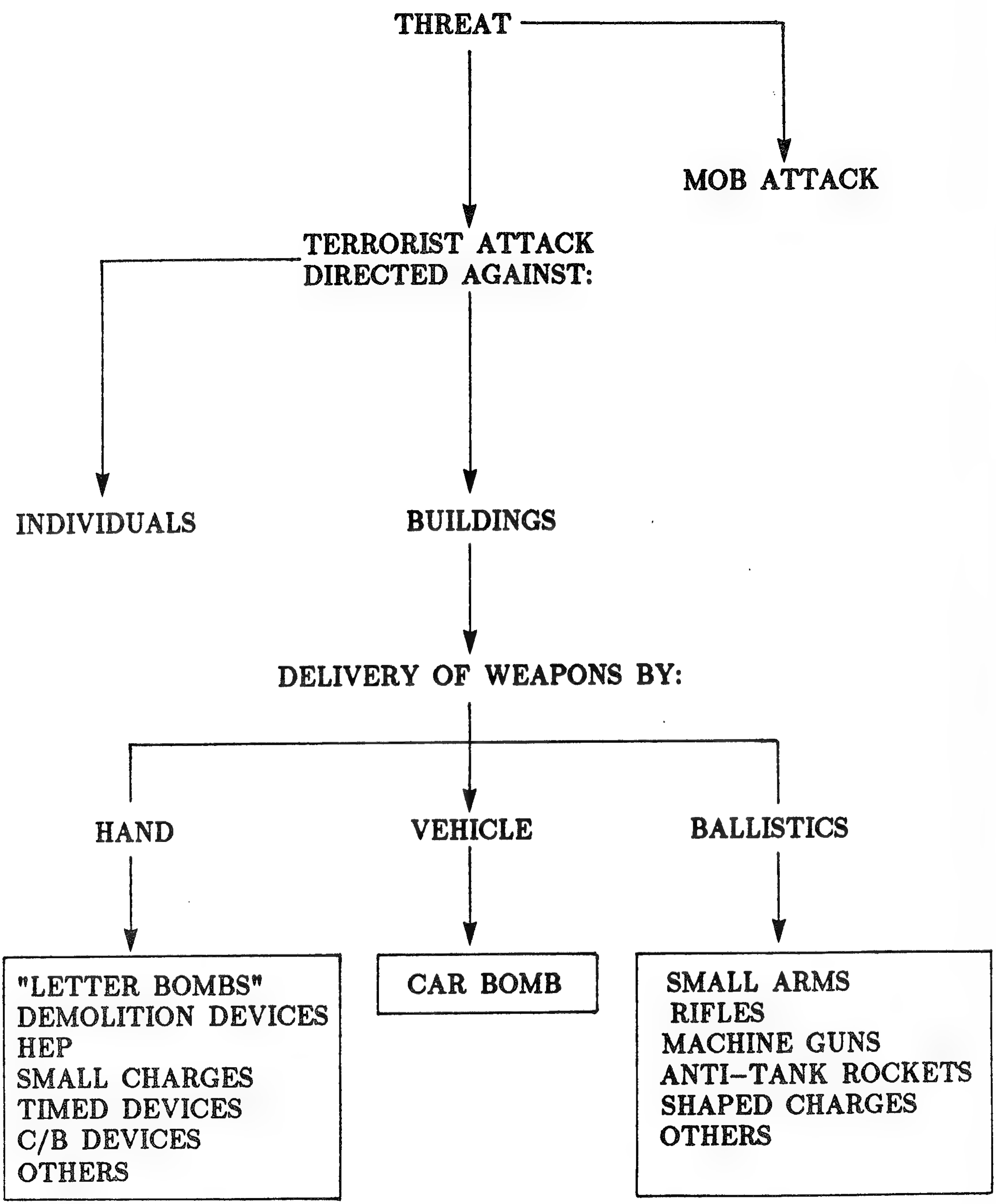
THREAT
MOB ATTACK
TERRORIST ATTACK DIRECTED AGAINST:
INDIVIDUALS
BUILDINGS
DELIVERY OF WEAPONS BY:
HAND
VEHICLE
BALLISTICS
"LETTER BOMBS"
DEMOLITION DEVICES
HEP
SMALL CHARGES
TIMED DEVICES
C/B DEVICES
OTHERS
CAR BOMB
SMALL ARMS
RIFLES
MACHINE GUNS
ANTI-TANK ROCKETS
SHAPED CHARGES
OTHERS

FIGURE 1

**Anti-Tank Rocket/Grenade Attacks by Terrorists**
*1971-1981 (Sept.)*

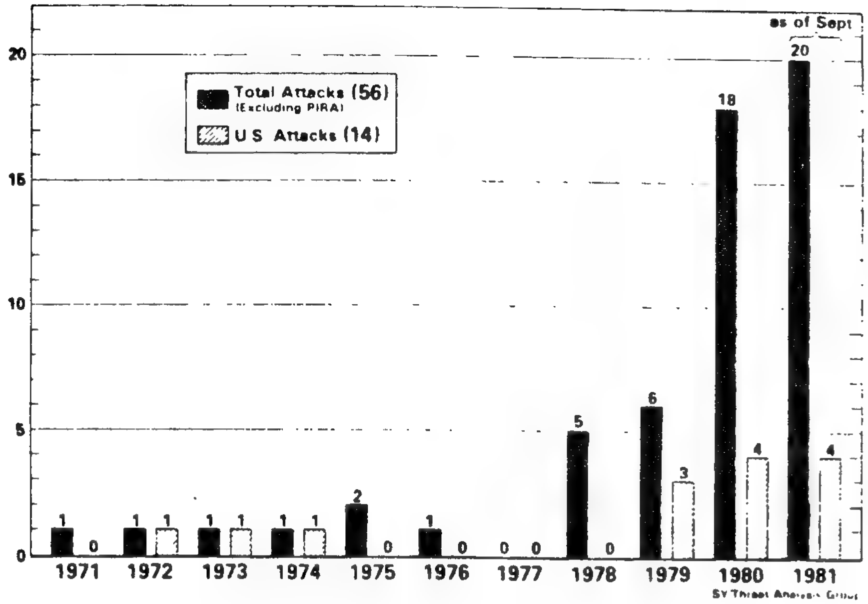


FIGURE 1. (Chart is Unclassified.)

**Proliferation of Different Terrorist Groups Using Anti-Tank Rockets/Grenades**

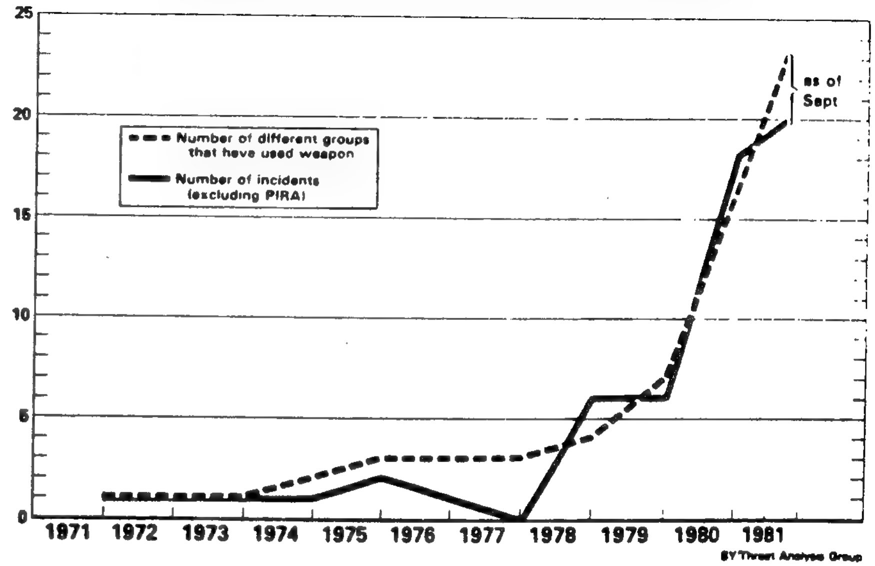


FIGURE 2. (Chart is Unclassified.)

001029

FIGURE 2.

Source: Terrorist Tactics and Security Practices:
Lessons Learned III
Department of State
Office of Security Threat Analysis
Group; Dec. 1981
CLASSIFIED: CONFIDENTIAL

## COUNTERMEASURES:


FIGURE 3

# PASSIVE COUNTERMEASURES

## STRUCTURE

Walls
Columns
Floors
Frame
Roof

**Hardening**

## PERIMETER

Fence – Wall
Bollards – Planters
Street Closing

## ACCESS

Vehicle Barrier – Traps
Guard House

**Perimeter Protection**

## ARHITECTURE

### PHYSICAL PLANNING

Glass
Window Frames
Fragment Mitigation
Emergency Equipment

### FUNCTIONAL PLANNING

Crisis Management
    Search / Rescue
    Evacuation / Assembly
Access Control
Driveway Geometry
Parking
Airblast Mitigation Geometry

**Atchitectural Planning**

FIGURE 4

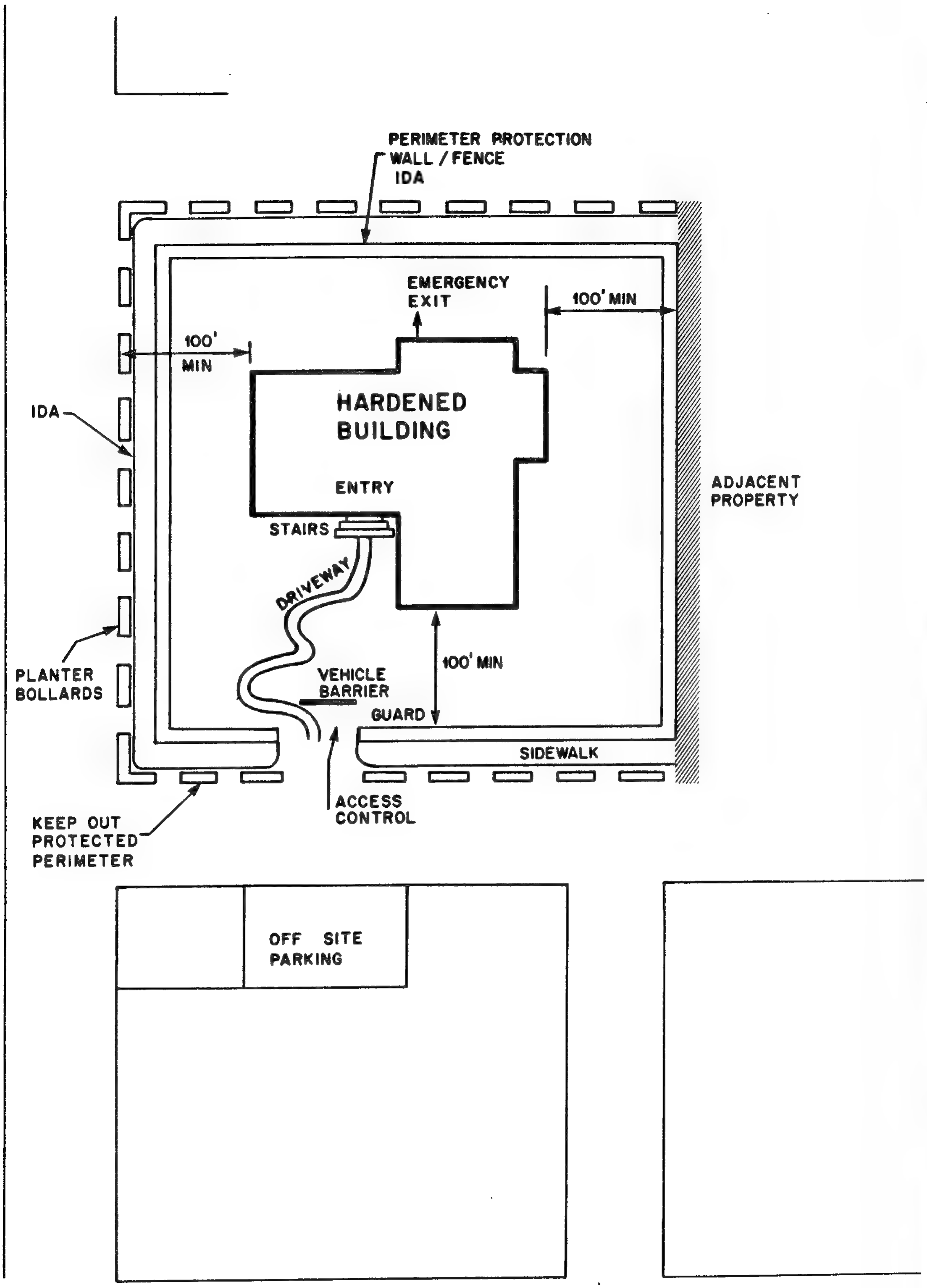


FIGURE 5

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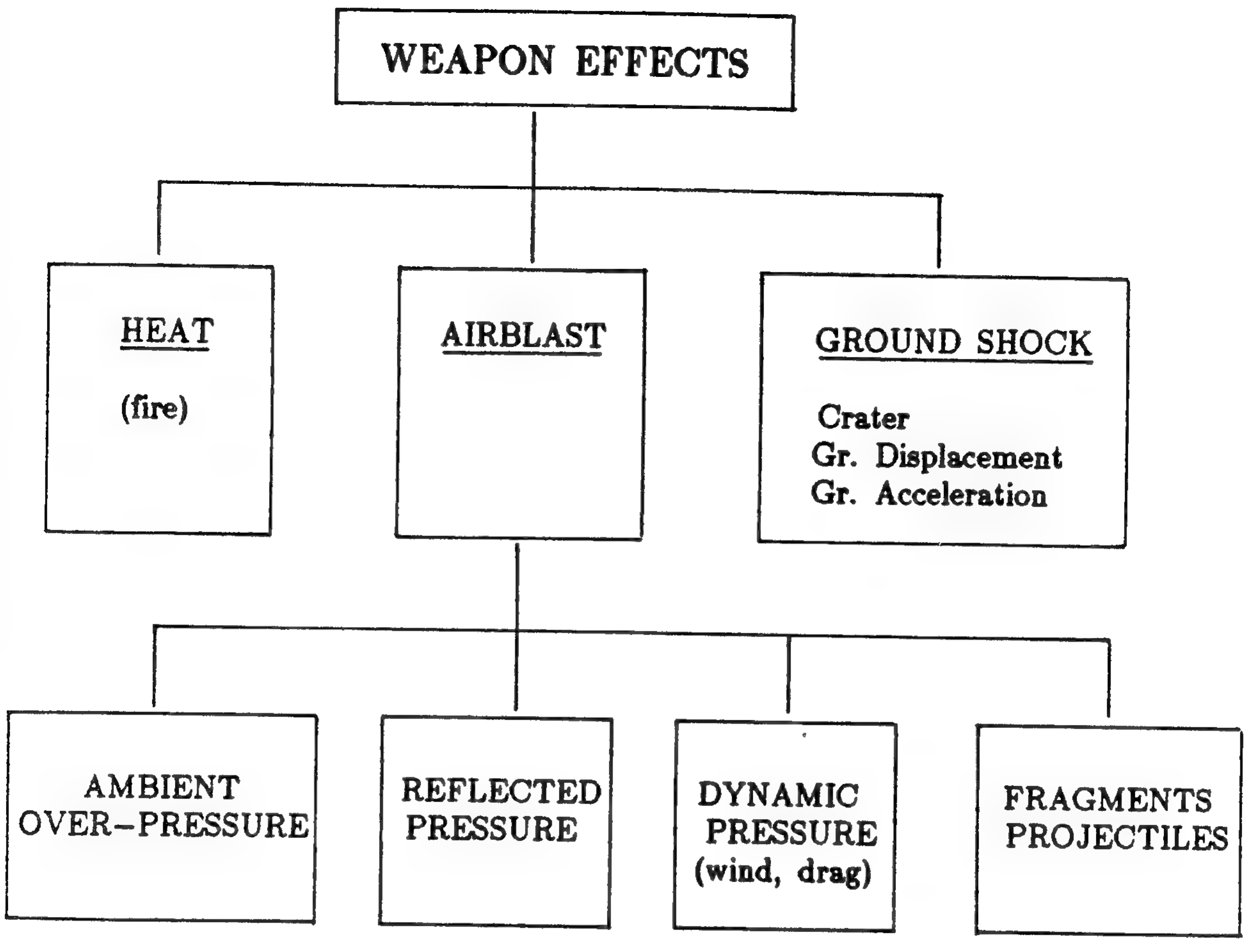

WEAPON EFFECTS
HEAT
(fire)
AIRBLAST
GROUND SHOCK
Crater
Gr. Displacement
Gr. Acceleration
AMBIENT OVER-PRESSURE
REFLECTED PRESSURE
DYNAMIC PRESSURE (wind, drag)
FRAGMENTS PROJECTILES

FIGURE 6

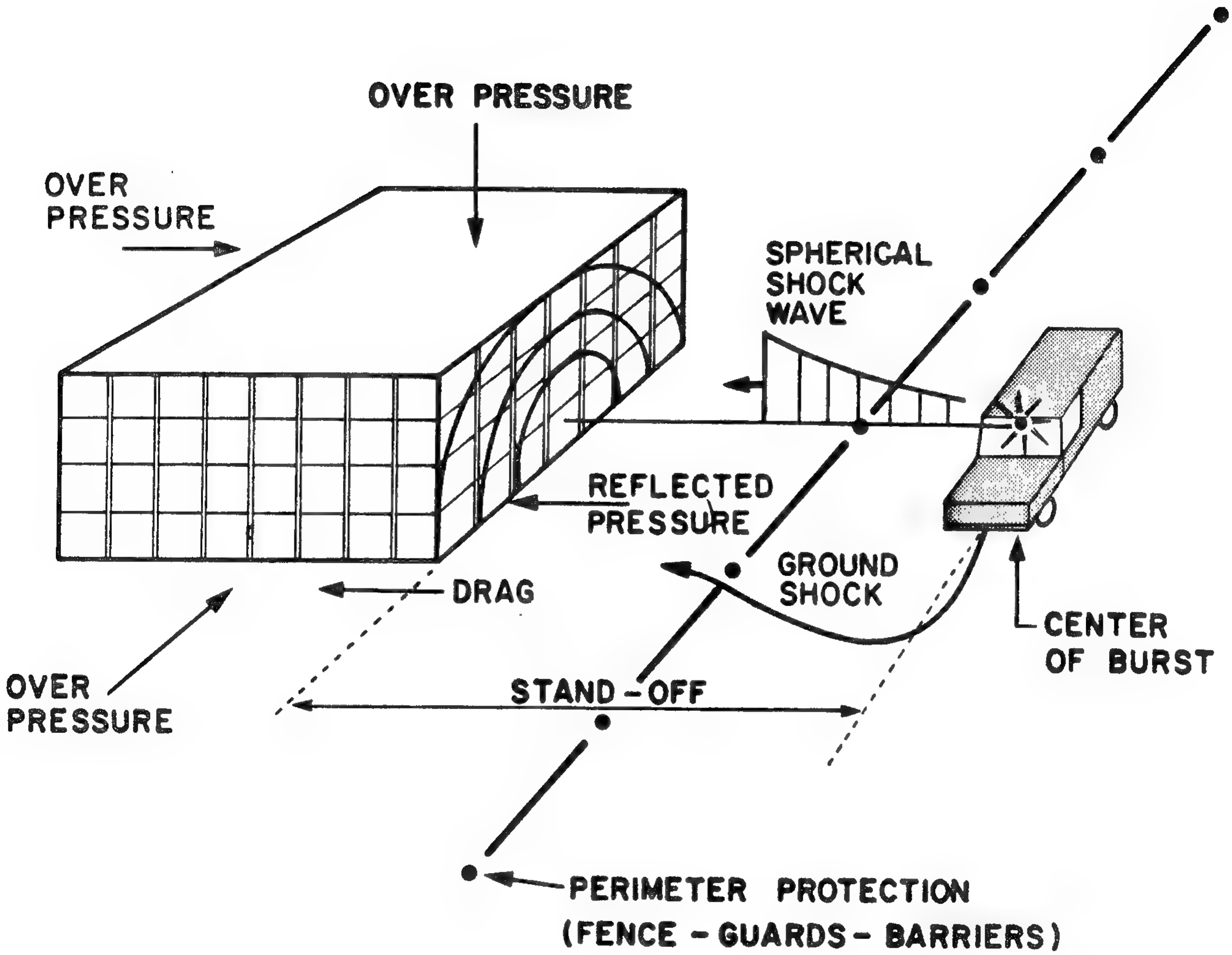



FIGURE 7

001034

| THREAT | | AIR-BLAST PARAMETERS |
|---|---|---|
| CHARGE WEIGHT (W) | → | PRESSURE |
| RANGE (STAND-OFF) R | | IMPULSE |
| HEIGHT OF BURST (HOB) | | REFLECTIONS - DIFFRACTIONS |
| ANGLE OF INCIDENCE $\alpha$ | | SHOCK ARRIVAL TIME |
| | | DURATION |
| | | SHOCK VELOCITY |

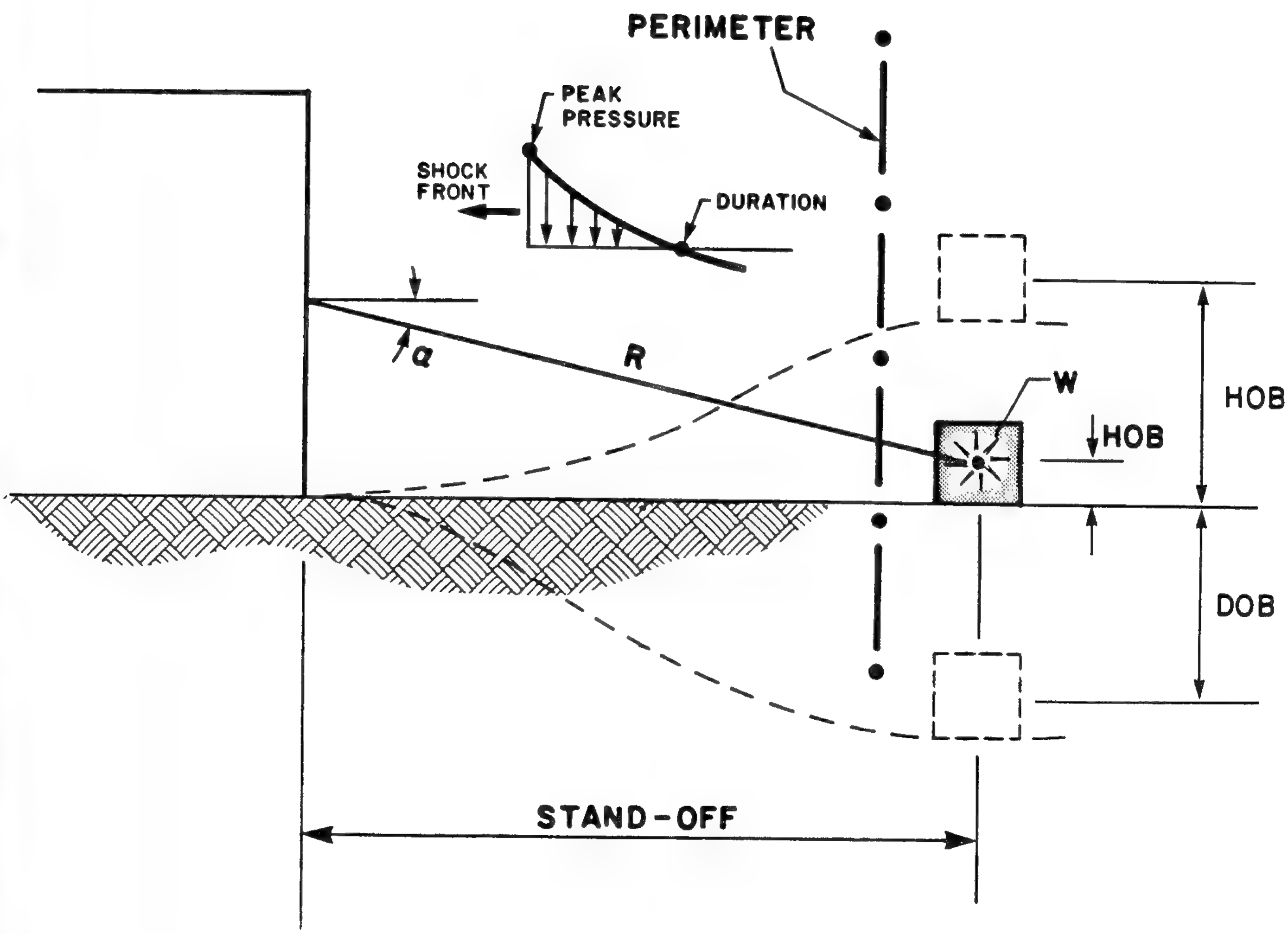
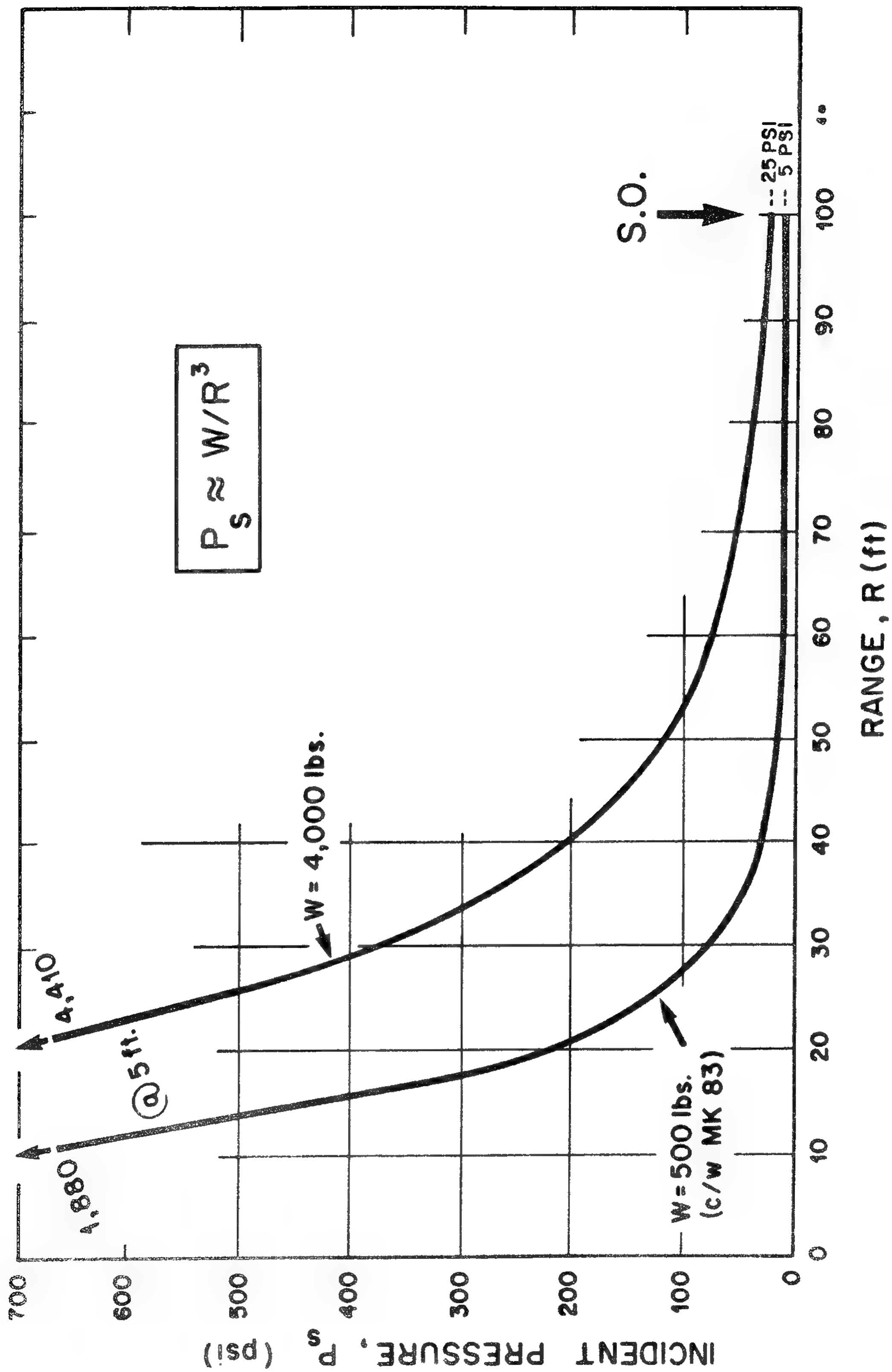


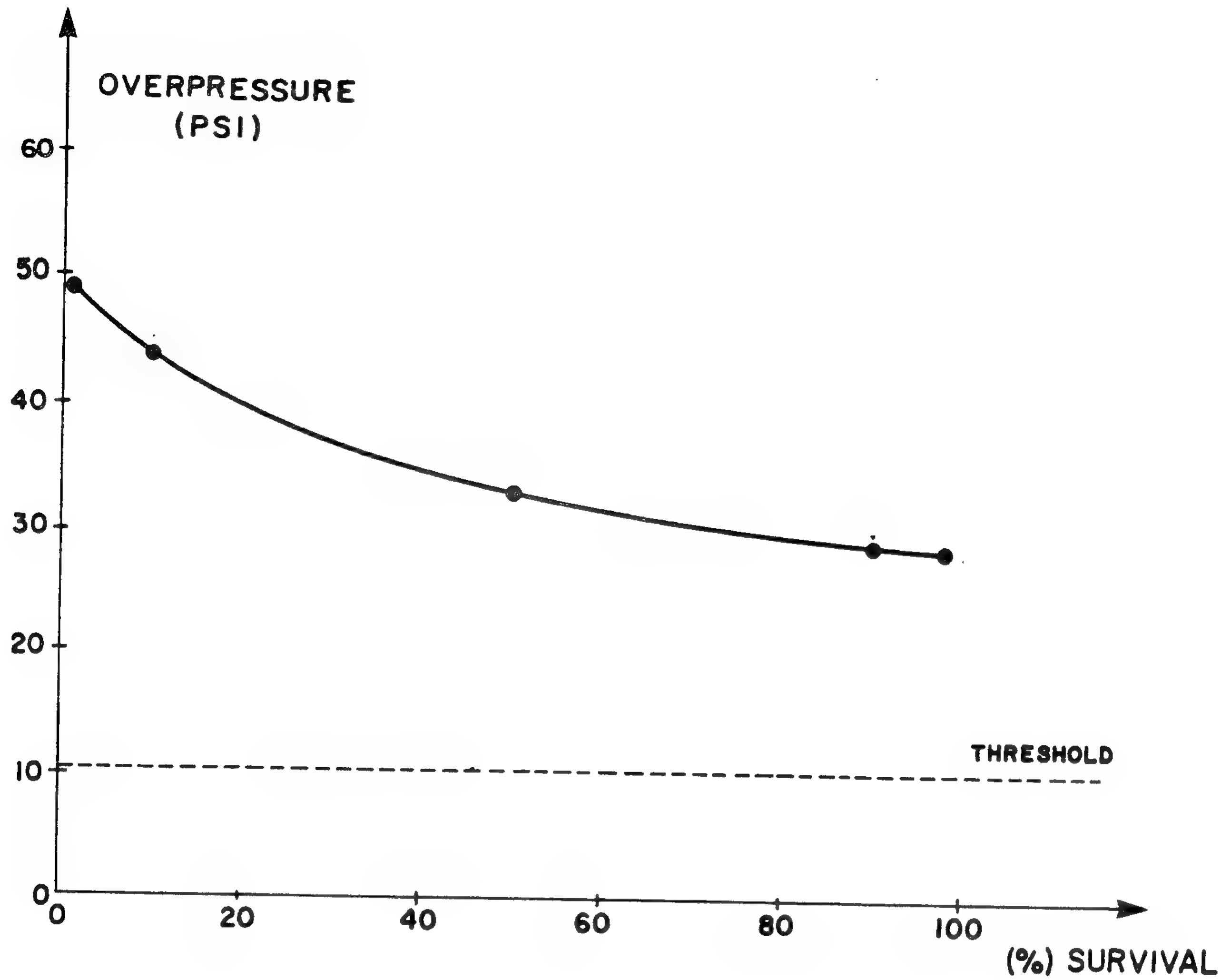

FIGURE 8




RANGE - EFFECT

FIGURE 9

001036

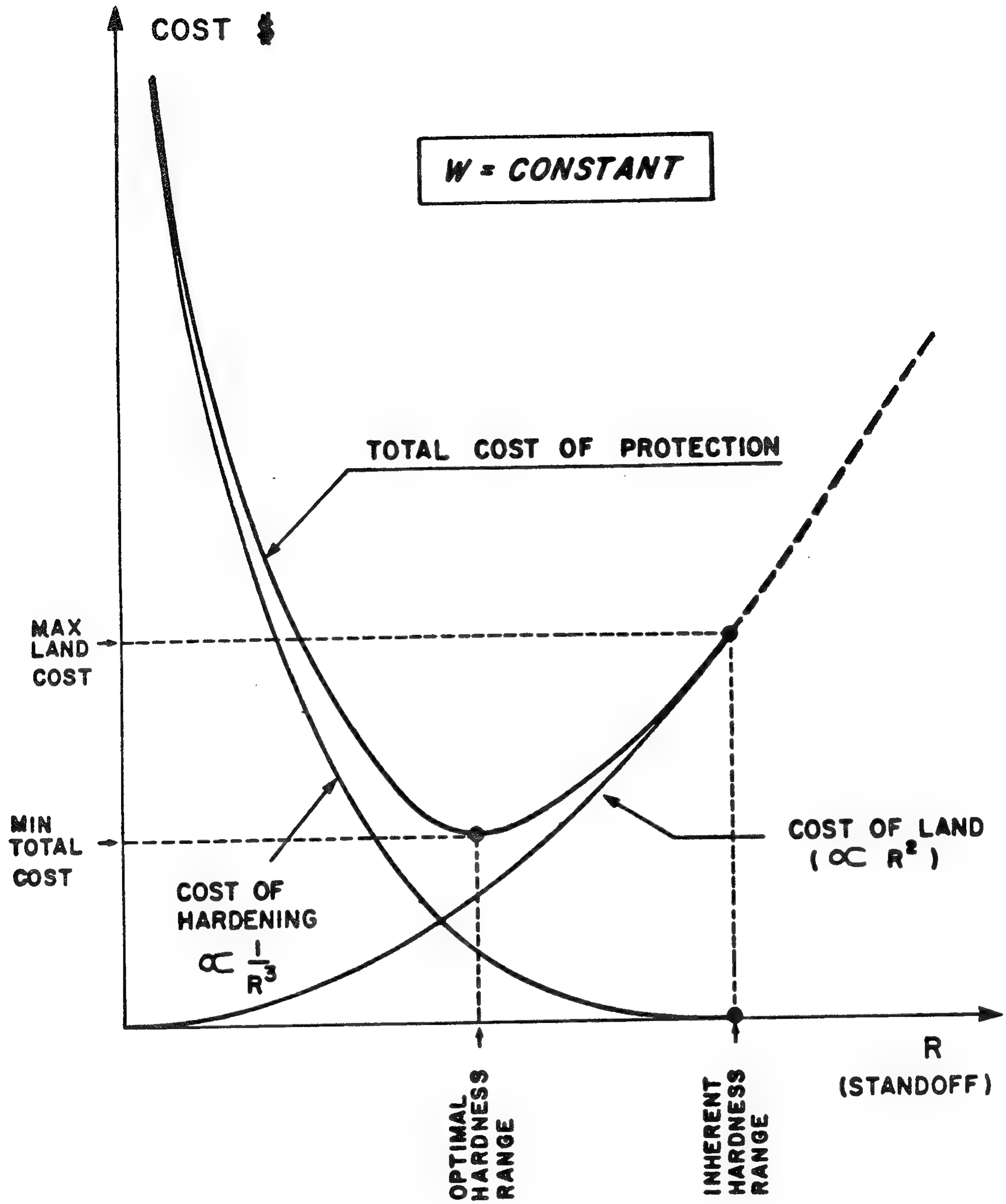



SURVIVAL FOR LUNG DAMAGE TO MAN
AT HIGH IMPULSE CONTENT

Based on:
Explosion Hazards and Evaluation by Baker, WE etal., fig 8–8
Elsevior Scientific Publishing Company, New York, 1983

FIGURE 10

001037




COST OF HARDENING - STANDOFF

FIGURE 11

001038

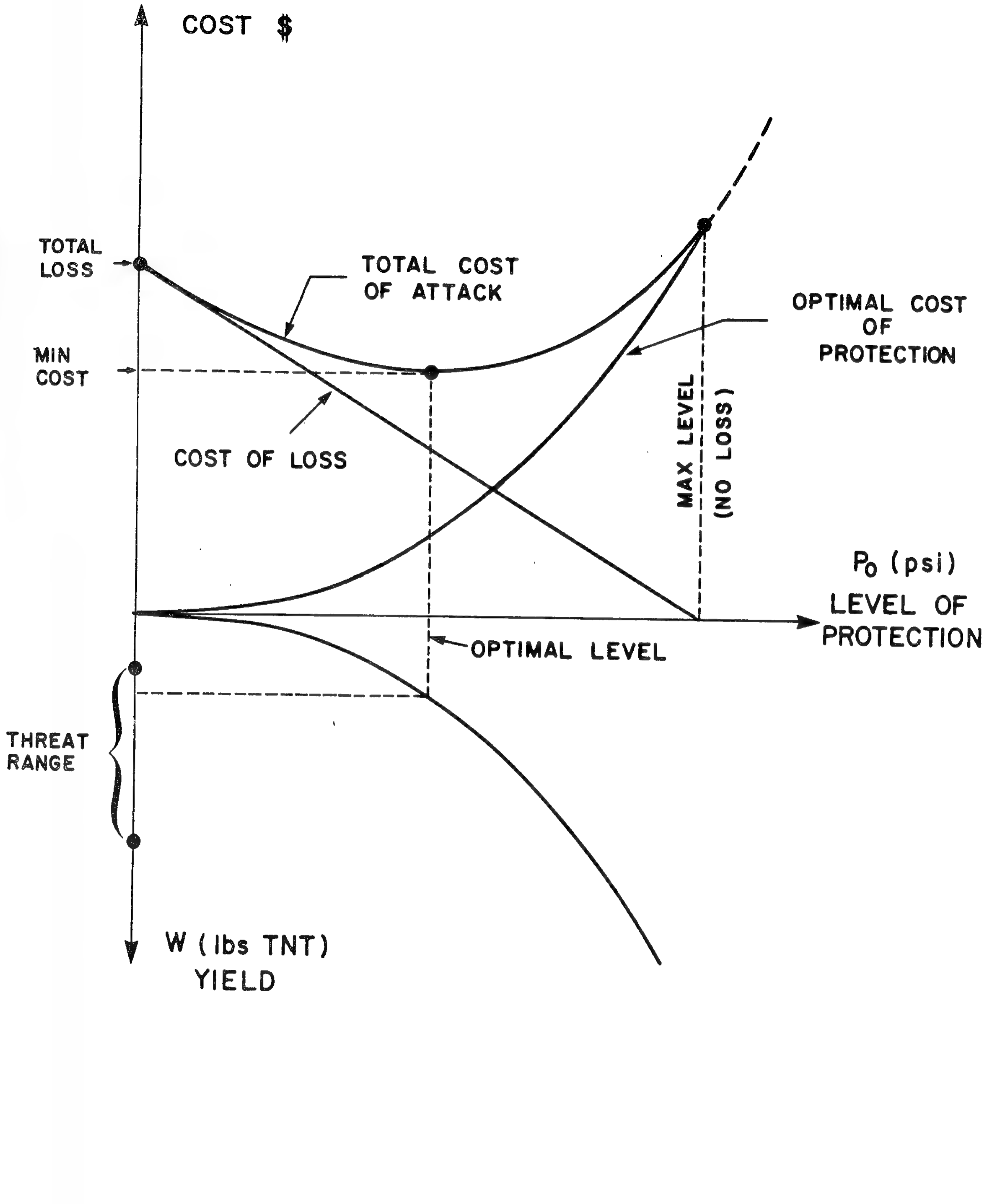

COST $
TOTAL LOSS
TOTAL COST OF ATTACK
OPTIMAL COST OF PROTECTION
MIN COST
COST OF LOSS
MAX LEVEL (NO LOSS)
$P_0$ (psi) LEVEL OF PROTECTION
OPTIMAL LEVEL
THREAT RANGE
W (lbs TNT) YIELD

FIGURE 12

# SYSTEM DESIGN

Risk is measured by the Probability of regrets

The system is designed to Minimize risk

## When risk is not quantifiable use:

Worst case analysis, or

Afortiori analysis

To Define $\left\{ \begin{array}{l} \text{Threat} \\ \text{and} \\ \text{Countermeasures} \end{array} \right.$

FIGURE 13

# ARGUMENTS FOR THREAT

Car bombs most frequently used

Cause maximum structural damage

Explosive yields used in past

$$500 < W < 12{,}000 \text{ lbs. TNT}$$

Structure can "survive" an explosion of

$$W = X \text{ lbs. TNT}$$
$$R = 100 \text{ ft. Standoff}$$

With high confidence

FIGURE 14

<u>with  X  lbs/100 ft. threat</u>

External appearance of U.S. embassies need not project an image of a fortification

It does not invite threat escalation

also, becouse

The marginal cost of hardening in seismic areas is less then 1% of construction cost

and

Every U.S. foreign post is a potential target

<u>ALL</u> U.S. embassies should be protected

FIGURE 15

# SEQUENCE

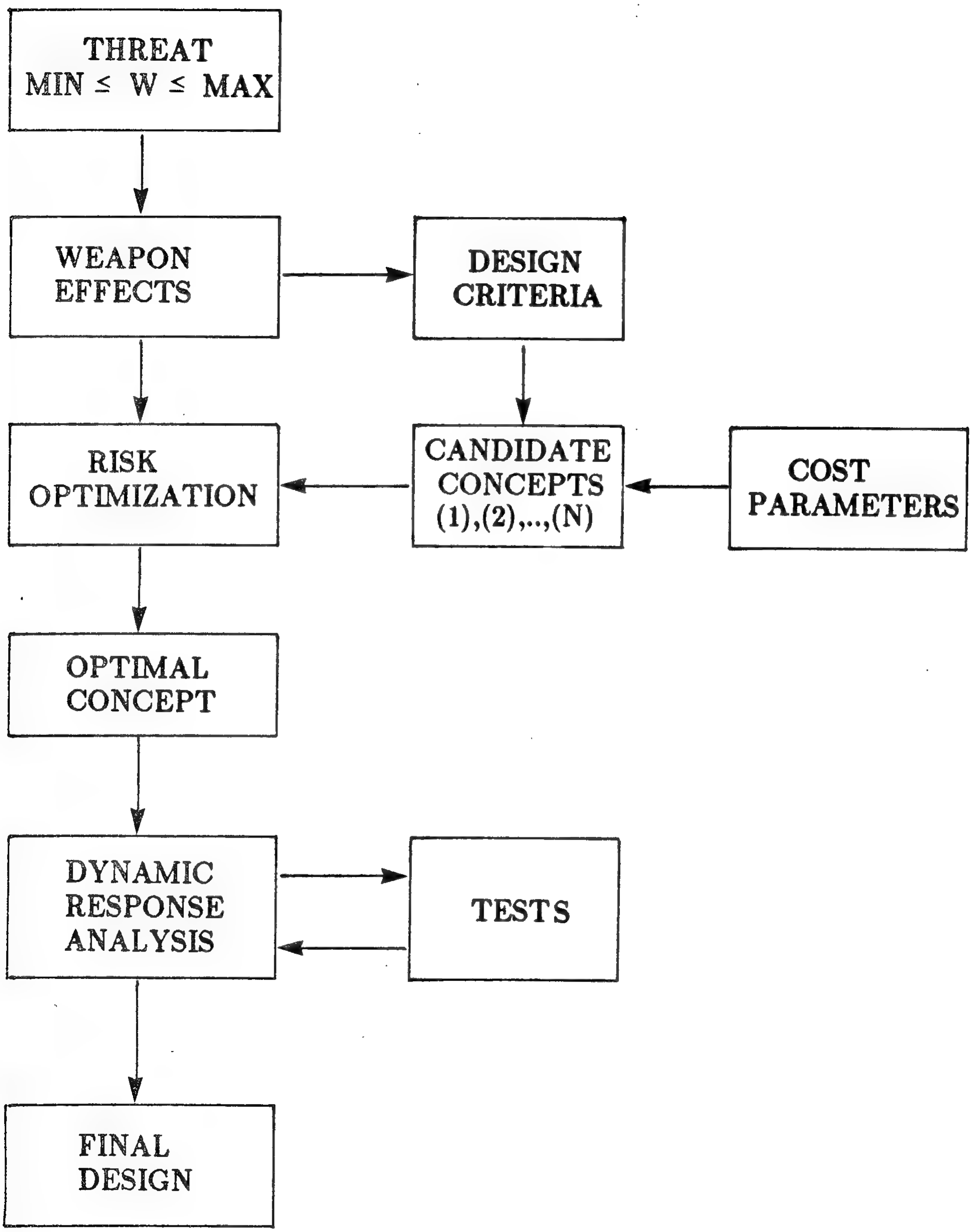
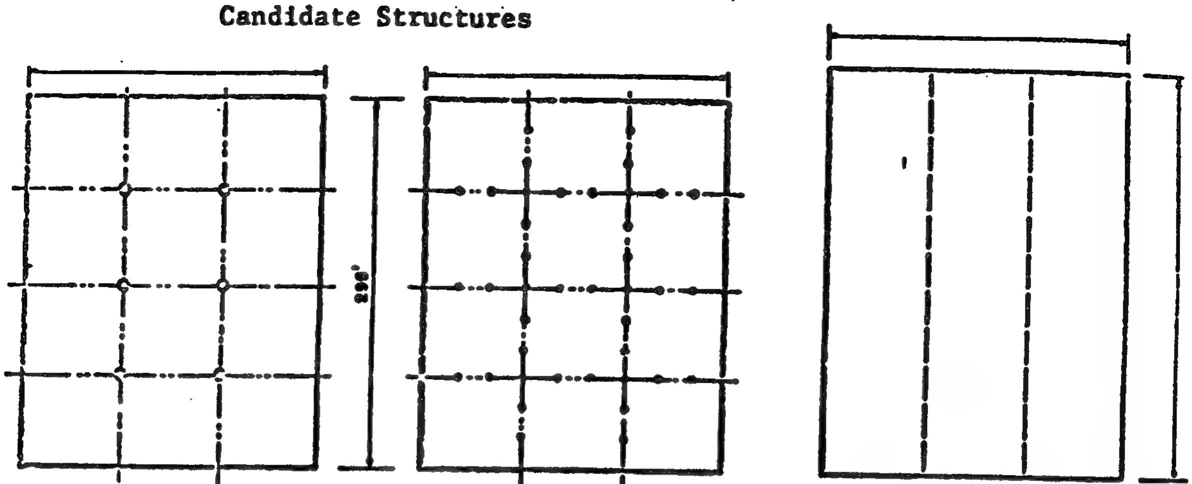


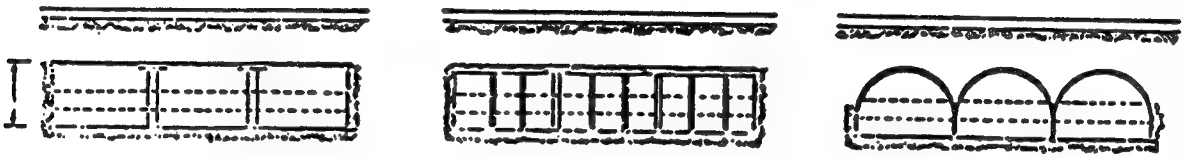

FIGURE 16

Candidate Structures

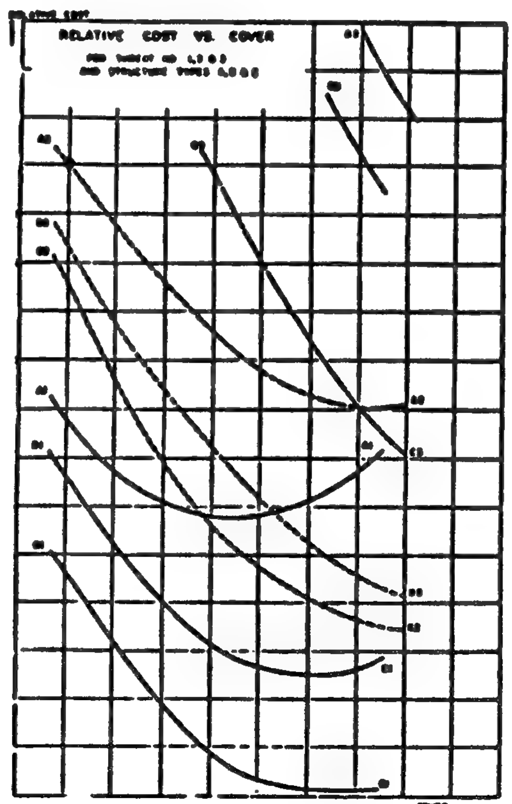


Type A Type B Type C

Plan



Section




Design and cost tradeoff

FIGURE 17

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# SEQUENCE OF AIR-BLAST RESPONSE

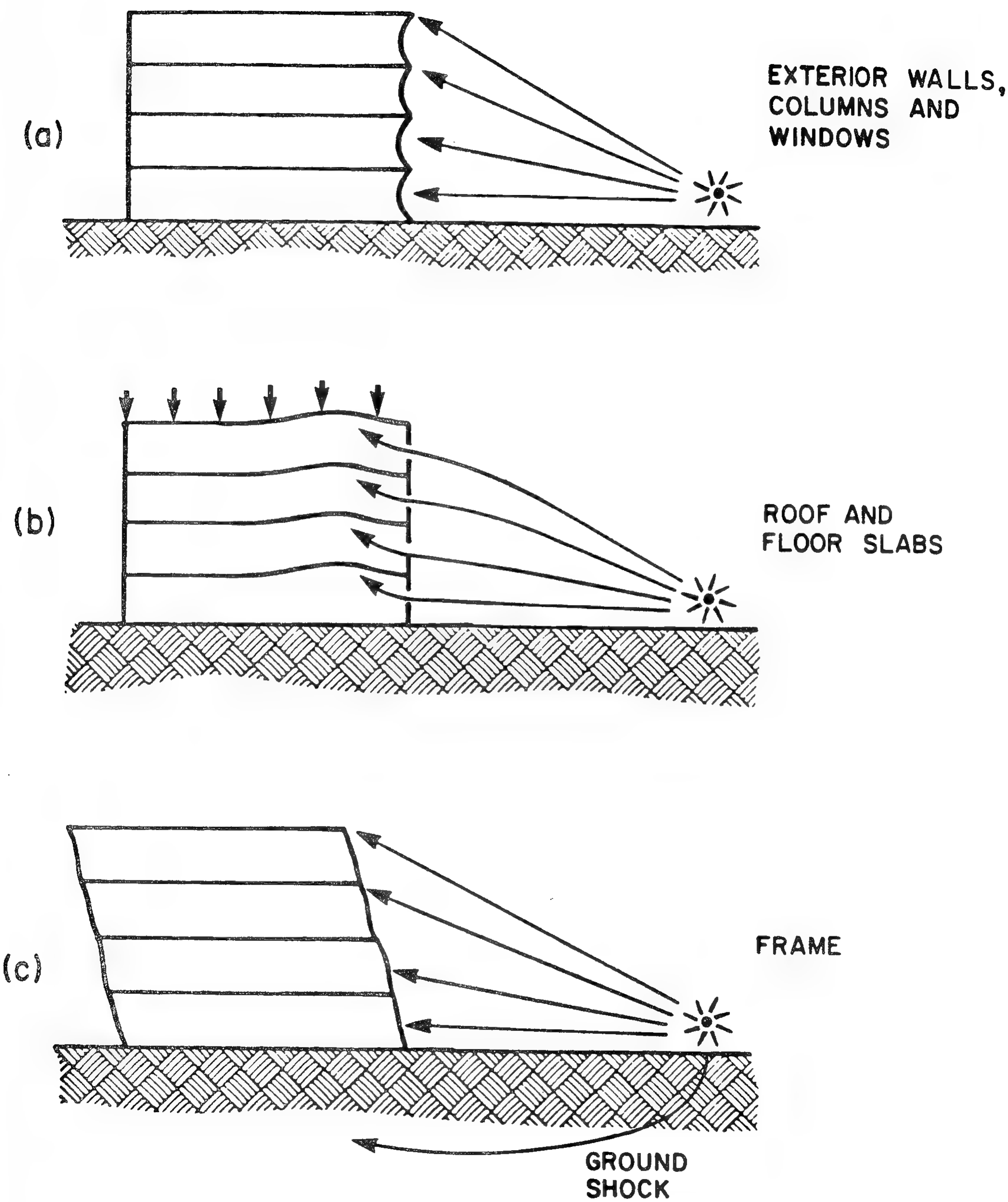


FIGURE 18

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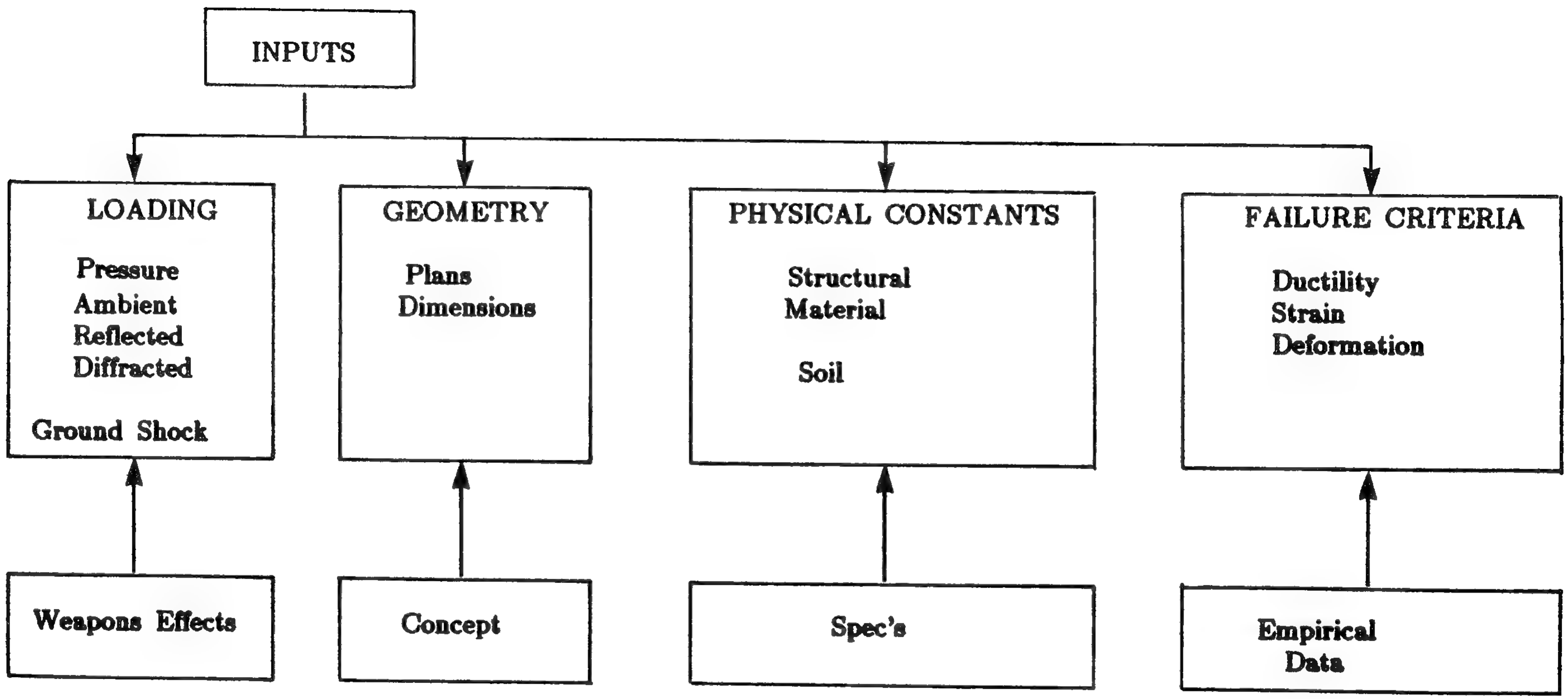



FIGURE 19

001046

# ANALYTICAL & NUMERICAL TECHNIQUES

| Model | Design Charts | SDOF | FEM |
|---|---|---|---|
| Input | Threat<br><br>Geometry Dimensions | Loading Function<br><br>Resistance Function | Loading Function<br><br>Geometry Dimentions |
| Output | Final Design | Approximate Response | "Exact" Response |

FIGURE 20

## EXTERIOR COLUMNS INTEGRAL WITH 12 IN. WALL

### Total Vertical Reinforcement

p = Total percentage of vertical reinforcement, (%)

$A_s$ = Total area of vertical reinforcement, ($in^2$)

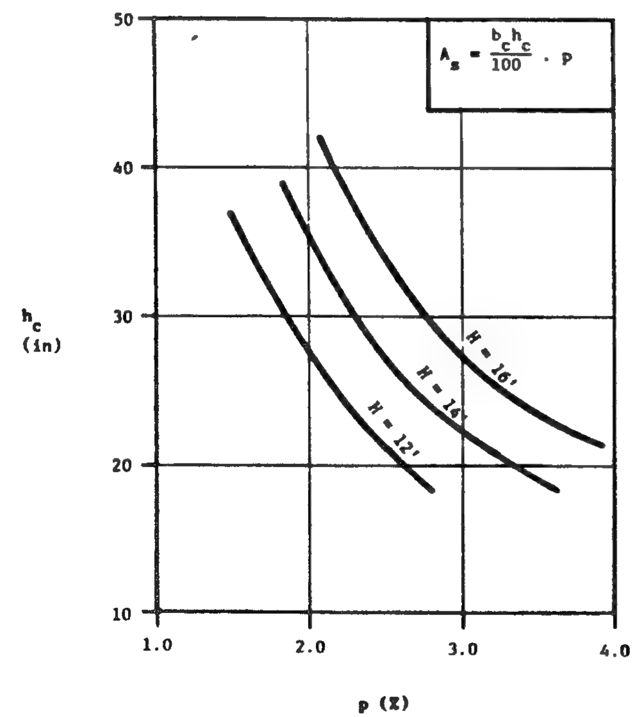
$b_c$ = Width of column, (in)

$\geq$ 12 in

$h_c$ = Depth of column, (in)

$t_w$ = Thickness of wall, (in)

H = Height of column, (ft)



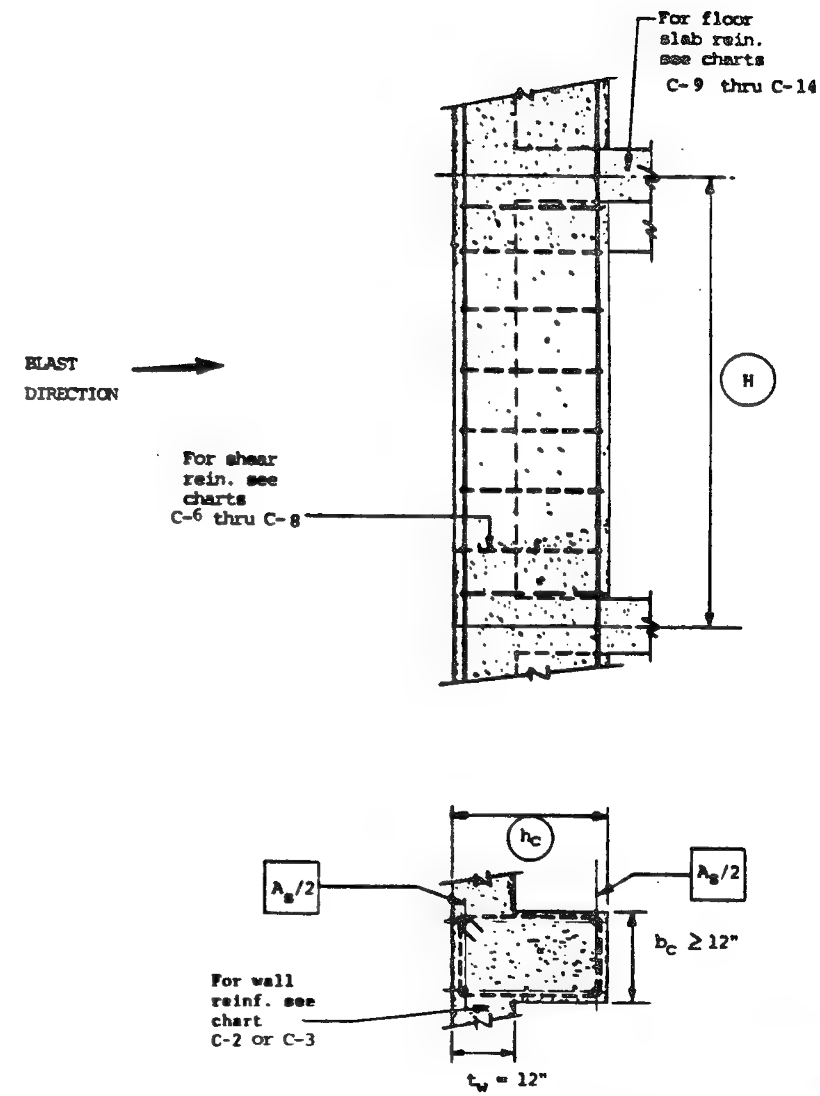




FIGURE 21

001048

## METHODOLOGY

STRUCTURAL COMPONENTS TO SATISFY MIN/MAX DIMENSIONS

STRUCTURE DESIGNED FOR NORMAL LOADS

ADDITIONAL REINFORCING FOR WEAPONS EFFECTS

## STRUCTURAL COMPONENTS AFFECTED

EXTERIOR WALLS

FLOOR SLABS OF EXTERIOR BAYS

ROOF SLAB

EXTERIOR COLUMNS

FRAMES OR SHEAR WALLS

## APPLICABILITY

REINFORCED CONCRETE STRUCTURE

100' STAND OFF

SIMPLE GEOMETRY

WINDOW OPENINGS LESS THAN 15% OF WALL AREA.

FIGURE 22

## 4.7 Procedures for Use of Charts and Diagrams

The use of the charts and diagrams assumes compliance with all proceeding and subsequent provisions of the guidelines. Specifically, the limit of the range of dimensions shown define the maximum span or height and the minimum acceptable width and/or depth of structural members.

With these charts and diagrams, the minimum addition reinforcing (beyond that required by standard design practice) can be determined, to resist the effects of the postulated explosion. To determine the required reinforcing in the structural members, the following procedure is used:

Step 1 - Select dimensions of members to satisfy minimum and maximum limitations, as defined above.

Step 2 - Determine by ACI code provisions the reinforcing required for factored DL only ($A_{DL}$) at the positions and locations shown on applicable diagram.

Step 3 - Determine standard reinforcing ($A^*_s$) at the identical positions and locations, required for critical combinations of factored DL and factored LL's, (including wind and earthquake) and/or minimum by ACI or UBC and refs. 4 and 9.

Step 4 - Find reinforcing ($A_s$) from applicable chart.

Step 5 - Provide reinforcing at positions and locations shown on diagram equal to

$$A_s + 0.87\ A_{DL}$$

but not less than the standard reinforcing ($A^*_s$) found in Step 3.

FIGURE 23

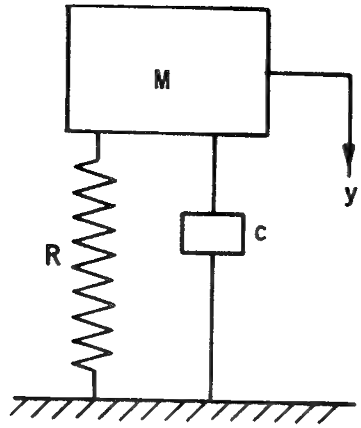



Figure 10-1. Single-degree-of-freedom system.

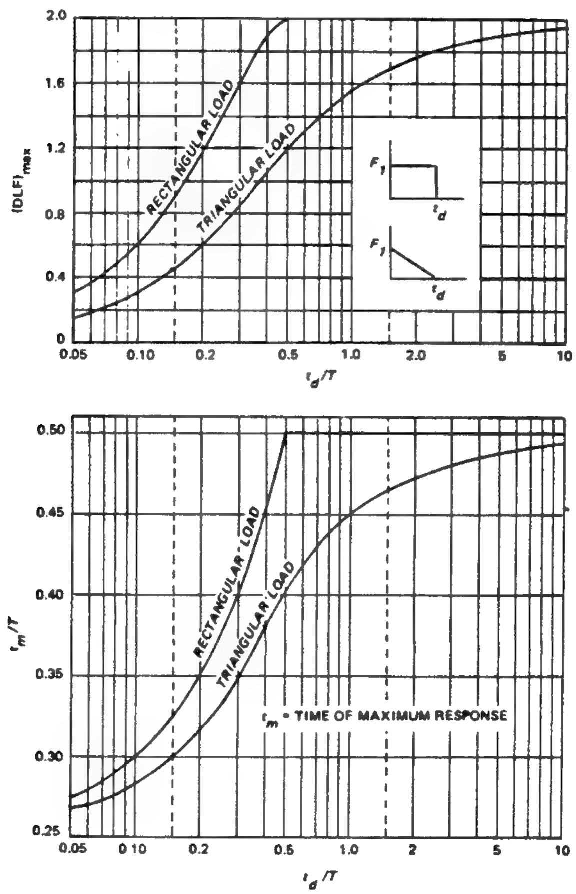
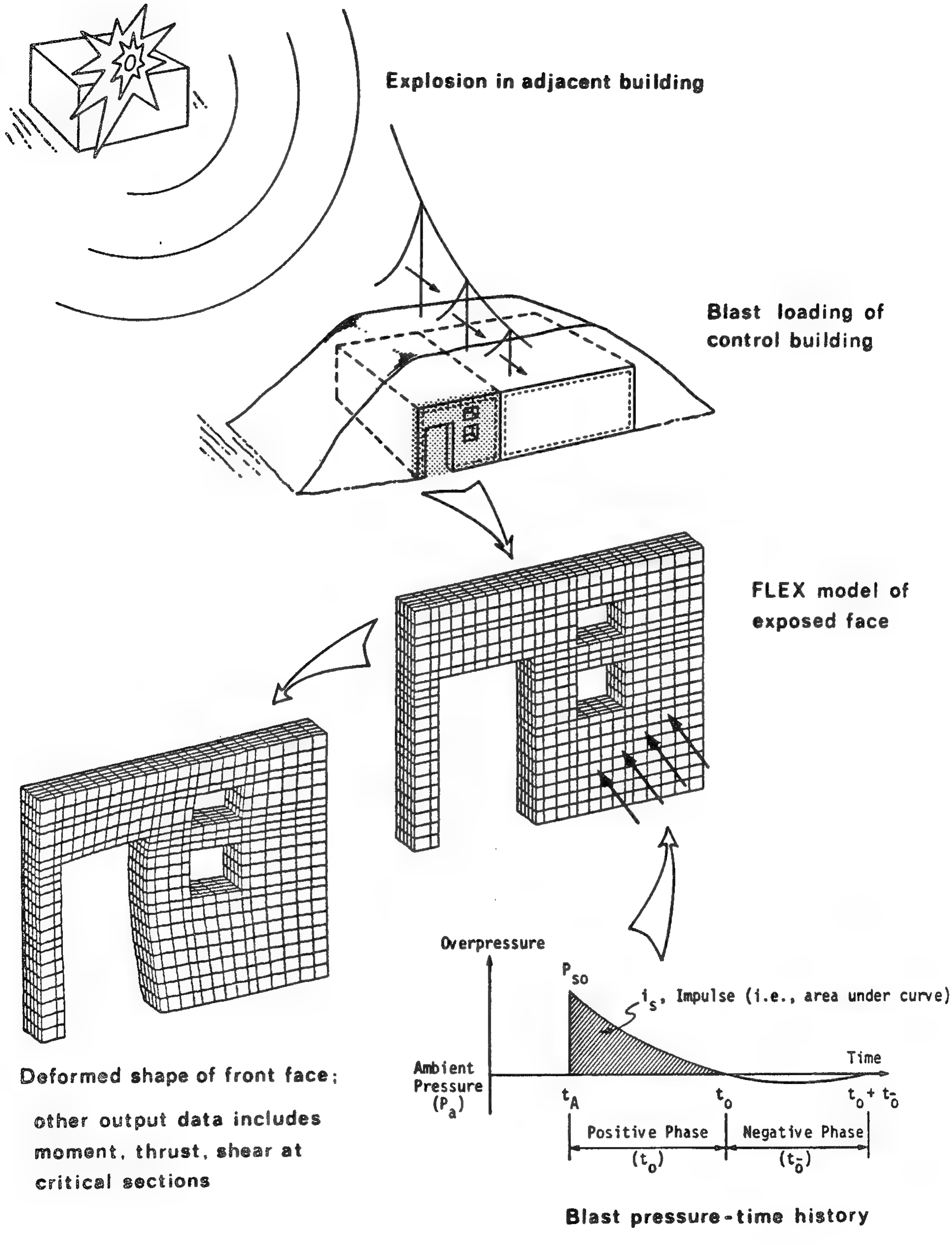



FIGURE 24




NONLINEAR ANALYSIS OF STRUCTURAL RESPONSE DUE TO ACCIDENTAL EXPLOSIONS

FIGURE 25

# PRACTICAL EXPERIENCE IN THE ANALYSIS, DESIGN, AND CONSTRUCTION OF STRUCTURES HARDENED TO WITHSTAND CAR-BOMB ATTACKS

J. M. Musacchio, Paul C. Rizzo Associates, Inc.
R. Eytan, EBD International, Ltd.

## ABSTRACT

One of the objectives of this conference is to provide a forum for the exchange of data resources, technology, and experience related to securing installations against car-bomb attacks. With this theme in mind, the authors thought it prudent to share some of our experiences within the design professional community for protected and hardened structures.

Our experience in developing protective measures for a variety of structures and facilities in Europe, the Middle East, Southeast Asia, and Africa has resulted in a logical program which entails the role of the design professional (architect-engineer or consultant), interaction with owners, identification of key aspects of design criteria, and the development of protective design principles, design guidelines, and cost effective design measures. This process has evolved to a point where a general program of procedures can be outlined for use by the design community in developing site specific, optimal protective measures for structures against car-bomb attack. This program is presented in this paper for consideration by the designer as he faces the challenge of developing structures and facilities that are functional, cost effective, aesthetic, and safe. Key elements of the program include:

- Threat Definition
- Analyses of Car-Bomb Effects
- Protective Design Criteria
- Protection, Hardening, and Security Measures
- General Architectural and Engineering Protective Design Principles
- Cost Effectiveness of Various Design Options
- The Design Professional's Protective Design Guidelines and Requirements
- Design Review
- Construction
- Applications for Existing Structures

# PRACTICAL EXPERIENCE IN THE ANALYSIS, DESIGN AND CONSTRUCTION OF STRUCTURES HARDENED TO WITHSTAND CAR-BOMB ATTACKS

J. M. Musacchio, Paul C. Rizzo Associates, Inc.
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## INTRODUCTION

One of the objectives of this conference is to provide a forum for the exchange of data resources, technology, and experience related to securing installations against car-bomb attacks. As a result of this exchange and associated developments, it is hoped that the quality of equipment, architectural and engineering solutions, construction, operations, and maintenance of our car-bomb related countermeasures can be substantially improved.

With this theme in mind, the authors thought it prudent to share some of our experiences within the design professional community for protected and hardened structures. During the past fifteen years, the increase in terrorist activities has raised new, albeit unwelcome challenges to the design professional. No longer are the development of blast loadings, vulnerability and threat analyses work-scope items strictly for military engineers and their consultants. A much broader segment of the design community must now become involved. As the terrorist and his arsenal become more high-tech, the more difficult our task becomes.

Nevertheless, our experience in developing protective measures for a variety of structures and facilities in Europe, the Middle East, Southeast Asia, and Africa has resulted in a logical program which entails the role of the design professional (architect-engineer or consultant), interaction with owners, identification of key aspects of design criteria, and the development of protective design principles, design guidelines, and cost effective design measures. This process has evolved to a point where a general program of procedures can be outlined for use by the design community in developing site specific, optimal protective measures for structures against car-bomb attack. This program is presented in this paper for consideration by the designer as he faces the challenge of developing structures and facilities that are functional, cost effective, aesthetic, and safe. Key elements of the program include:

- Threat Definition
- Analyses of Car-Bomb Effects
- Protective Design Criteria
- Protection, Hardening, and Security Measures
- General Architectural and Engineering Protective Design Principles

- Cost Effectiveness of Various Design Options
- The Design Professional's Protective Design Guidelines and Requirements
- Design Review
- Construction Monitoring
- Applications for Existing Structures

## THREAT DEFINITION

Ideally, a client will provide the design professional with a full definition of the threat, in our case, a comprehensive description of the car bomb against which the installation must be secured.

The following parameters should be clearly defined:

- The type of car bomb: automobile, truck, etc., or alternatively the definition of the exact location of the center of the explosion.

- The car bomb location relative to the structure: distance, elevation, orientation, etc.

- The amount and type of explosive of the car bomb or alternatively the equivalent TNT explosive quantity.

- Any additional car-bomb characteristics such as fire inducing devices, nails, or other anti-personnel missiles, etc.

Our practical experience has shown that more typical initial "threat definitions" by different clients include:

- We want car-bomb protection, it is your business, and your job to provide it--that's why we pay you anyway.

- We do not have a clue; ask the authorities, the defense forces, the police, the research institutes, the intelligence and security experts, etc.

- Give us a few alternative threat definitions and we will decide which one to design against.

- What would you recommend?

In most cases, the appropriate parameters of threat definition are developed through a constructive dialogue conducted by the design professional in which the client will try to provide the best threat

definition that suits his needs while the design professional will provide the necessary technical information and the construction/financial implications for the envisioned threat.

## ANALYSIS OF THE CAR-BOMB EFFECTS

The design professional should be able to estimate the following general/free-field effects induced by a car-bomb explosion:

- Blast
- Primary and secondary missiles and debris
- Cratering
- Ground shock
- Fire
- Smoke and toxic gases

Consideration of the site conditions and the designated structural configuration, should enable the design professional to estimate the influence of the above car-bomb effects on people, equipment, and structural components. This involves an accurate calculation of the propagation of the free-field effects from the explosion point to the structure, the analysis of the interaction of the car-bomb effects with the structure and estimation of the structural response and in-structure effects on people and equipment. Ideally, the design professional is capable of performing the above analysis of the car-bomb effects using the relevant existing information.

Our practical experience has shown the following to often be the case:

- The design professional's staff is not trained in analyzing the above car-bomb effects (the subject is not taught at any university and until recently, engineering-type data from actual occurrences has been extremely scarce, and generally not available to the design community).

- The design professional's staff has limited access to the most accurate and updated information (many relevant references are available outside the United States--the proceedings from this conference should improve this situation).

- The use of different manuals and guidelines leads to calculation results which differ by as much as a factor of five. The design professional is then faced with the difficult task of deciding which analytical procedure is most appropriate.

- The design professional's staff has limited (if any at all) practical experience in the field of car-bomb effects.

In most cases, the design professional will complement the capabilities of his staff with specialized consultants to perform the analysis of the car-bomb effects. The sources of information providing adequate data which enable the analysis of the car-bomb effects on people, equipment, and structures include:

- Literature references: manuals, books, reports, university thesis, etc.
- Symposium proceedings.
- Reports on laboratory and field tests.
- Computer software for different calculations.
- Surveys of actual attack descriptions and consequences.
- Description of actually built hardened installations.
- Catalogues of hardening and protection structural components.

Ideally, all of the above sources of information would be concentrated in a central data and information center to which interested parties with appropriate security clearances would have access. To the best of our knowledge at the time of writing this paper, such a comprehensive data and information center does not yet exist; several organizations do hold partial information in the field but they are spread around the country and access to the information is relatively difficult. Conferences such as this may be considered as an initial step toward resolving this situation. During our many years of providing consulting services in the field of designing hardened structures against weapons effects and terrorist attacks, we have managed to acquire a considerable amount of pertinent worldwide information. This encourages us that such a central data center can indeed become a reality and be a real service to the profession.

## PROTECTIVE DESIGN CRITERIA

Definition of the threat and subsequent estimates of the car-bomb effects on the structure or facility lead to the next decision point in the design process--development of appropriate design criteria. Ideally, on the basis of the effects estimate, cost of structural

replacement, cost of loss of services, and, of course, loss of life a comprehensive protective design criteria should be specified by the client. This criteria should include a clear definition:

- Of the acceptable level of damage/protection:

  - The acceptable blast levels, displacements, velocities, and accelerations for people inside the structure.

  - As above, for the equipment inside the structure.

  - The acceptable level of damage for all structural elements expressed in terms of displacements, level of acceptable concrete spalling, etc.

- If the structure should be designed to withstand a single car-bomb explosion or perhaps more than one and at which time intervals.

- Of the provision of flexibility to upgrade the level of protection of the structures in the future and if possible, to what extent.

- Of other threats which the structures have to withstand other than car bomb, such as portable weapons, long range projectiles, etc.

Our practical experience has shown that in most cases the client is not aware of the above design criteria and does not provide clear and defined requirements. Consequently, the design professional must provide the client with options available for inclusion in the protective design criteria and assist the client in development of the final set of protective design criteria. To provide this service, the design professional must be experienced in threat assessment, the actual performance of structures when subjected to car-bomb attack, and other terrorist threats.

## PROTECTION, HARDENING AND SECURITY MEASURES THE TOTAL CONCEPT

To effectively develop a design which satisfies the criteria, one must be sure to view the security measures as a total concept and not restrict or bias ones perspective from a civil, structural, mechanical, etc., viewpoint. Ideally, the design capabilities available to the client include a complete range of security measures; i.e., A/E protection and hardening measures, security systems, security guard

facilities, and working procedures. Only the balanced, optimal integration of all the above measures will provide the best protection of an installation against car-bomb attacks.

Unfortunately, it is practically impossible to find a single design entity with all the above capabilities. Primarily because some of the components of these security measures are not of an architectural-engineering nature. Furthermore, today we find many consultants, advisers, manufacturers, etc., offering "total security" to clients. When analyzed in depth, many of these specialists bias their services toward specific hardware. In our opinion, no installation can be optimally secured when the protection is built around specific security and hardening components marketed by manufacturers and developers.

The design professional must coordinate, based on the client's requirements and on the design parameters specific for each installation, architectural and engineered protection and hardening measures with the other security measures such as:

- Access control systems
- Intrusion detection and alarm systems
- Surveillance systems and installations
- Patrolling and security guard response means and facilities
- Security systems and security guard control facilities

This can be accomplished by using specialist security consultants experienced in the design of the above systems and integrating their recommended systems and installations with architectural and engineering considerations. Security hardware can then be specified which suits the overall requirements of the project at hand--first by considering the design criteria as a whole and only then choosing the appropriate security measures--not the other way around.

## GENERAL ARCHITECTURAL AND ENGINEERING PROTECTIVE DESIGN PRINCIPLES

### FUNCTIONAL DESIGN WITHIN PROTECTIVE CONSTRAINTS

One of the basic A/E design principles for a hardened installation is that first it must retain all its functional abilities, and second it should be adequately protected against the defined threats. Too often hardened structures are designed and built worldwide with the protection overriding the functional requirements. Unfortunately, we witness the construction of fortress-like, bunker-looking protected structures which sometimes cannot adequately perform their function because of the excessive implementation of protective hardening measures.

Protection and hardening requirements often conflict with the normal functional design requirements and are a heavy burden. Therefore, it is a real challenge for the A/E to implement the best protection measures

with minimal disturbance to the functions the structure must perform. Our practical experience has centered in the last 10 years on trying to achieve the goal of designing and building normal, functional, and aesthetic hardened structures.

## PEOPLE-ORIENTED HARDENING AND PROTECTION MEASURES

Although some structures principally house equipment; e.g., telephone exchanges, transformer stations, generator buildings, etc., most structures are built for the use of people. Consequently, these structures must provide for human needs such as adequate lighting, ventilation, air temperature, and humidity control and create a pleasant work or life environment. It is indeed a challenge for the design professional to provide all the aforementioned for physiological human needs as well as a setting of psychological tranquility. The latter is particularly difficult in a hardened structure where people would naturally be under a certain stress knowing that an attack might occur.

Our early experience included designs of hardened structures which were adequately strong but from which people escaped during attack because they could not stay inside due to physiological factors such as panic, the need to communicate, the need to know what is happening, etc.

We have learned that the designer should direct a very substantial effort toward designing protection and hardening measures which will be the best suited for the people's physiological and psychological needs expected at the time of the attack.

## BALANCED PROTECTIVE DESIGN

There is no real possibility of constructing a perfectly protected structure as every structure includes some breach in its envelope such as windows, doors, equipment openings, ventilation openings, service penetrations, etc. Naturally, these elements are weaker than the structural envelope. As a result, protective designs are often unbalanced because of the lower level of protection afforded these elements.

Our experience has shown that the designer must consider the above and provide a balanced protective design. All naturally weak elements must be given special attention to provide additional strengthening elements to raise their level of protection as close as possible to that of the structure. Many structures have failed to provide adequate protection for people and equipment inside due to the failure of the weaker elements under actual attack conditions.

## USE OF OPTIMAL MATERIALS AND CONSTRUCTION METHODS

Unfortunately, very rigid standards, codes, and regulations used in many countries are specifying certain materials and construction methods for structures hardened against conventional weapons effects; many of these have been proven ineffective in the last few years.

The technology of construction materials and methods is progressing at a fast rate and many of the newer materials and construction methods actually improve the structural resistance to the car bomb and other weapons effects, often at a reduced cost. The restrictions imposed by these regulations make the use of new technologies difficult. Often, designers would opt to not fight the technical bureaucracy and would resort to outdated materials, designs, and construction methods. The ideal solution would, of course, be to use the latest modern materials and construction methods proven as being adequate for the required protection criteria. The practical problems a designer must face are twofold: being aware of the latest materials available and being satisfied that performance claims are accurate and reliable.

A practical solution of accessing these technologies is to retain the services of a specialist consultant to research and evaluate new technologies.

In the event the option of utilizing most recent technologies is not available, there is still a broad range of conventional materials available; e.g., reinforced concrete, steel, soil, rocks, etc., and many alternate construction methods from which to choose.

Our point is that there is no set of optimal materials and construction methods that can be used for all types of hardened structures in all site conditions. The design professional must select the most adequate materials and construction methods for the project at hand to withstand the defined threats.

PREVENTION OF PROGRESSIVE COLLAPSE

During a car-bomb attack, the explosion effects are generally localized to a certain part of the structure directly in front of the car-bomb location. It was shown in many cases that normally designed structures were severly damaged locally by the car-bomb explosion blast and have experienced progressive collapse; for example severe damage to ground floor structural elements induced the progressive collapse of the whole building. Therefore, a basic protective design principle is that the structure should withstand the car-bomb effects such that progressive collapse will not occur following severe local damage. In our experience, this requirement is feasible and can be implemented in a most cost-effective manner.

REPAIRABILITY OF DAMAGE

In many cases, design professionals assume their job completed when they have proven to the client that the hardened structure has been designed to meet the protection requirements.

Having observed the actual damage to numerous structures subjected to blast loadings from conventional weapons and explosives, we learned that the extent of the damage induced and, therefore, the effort required to repair the structural damages are always dependent on the type of materials, designs, and construction methods and details used.

Therefore, the use of materials, design concepts, and construction methods which both address the requirements of minimal damage to the structure induced by the car-bomb effects and quick and inexpensive repairability is a basic protective design principle.

FLEXIBLE DESIGN FOR FUTURE UPGRADING

Ideally, once a client has defined the threat and the hardened structure is built accordingly, no futher changes will occur as far as the threat is concerned. Of course, this is not the case.

Our experience includes the design and construction of structures to withstand a rigid set of protection criteria where the client's financial constraints did not permit considering further higher threats in the future.

Later, when these structures were subjected to real higher threats and, consequently, required strengthening, the client incurred substantially more cost than had allowances for future strengthening been incorporated in the initial design. In fact, in some cases, the actual structural strengthening was impractical and new structures had to be designed and constructed.

It is a basic protective design principle that flexibility for further upgrading should be incorporated in the initial design within reasonable economic limits.

## COST EFFECTIVENESS OF THE PROTECTION AND HARDENING MEASURES

As mentioned before, the protection and hardening requirements often encumber the functional requirements of a structure or facility. They are also a burden from a financial point of view because their cost is normally over and above the base construction costs.

In our practice, we have heard the following remarks and statements made by different clients:

- Hardening measures are so costly that we cannot afford them.
- Instead of hardening measures we will invest more in other security measures.
- "They" should get the potential attackers before they get to our installation, therefore, we should not harden it.
- Instead of hardening we will pay insurance and will be covered in case of an attack on our installation.

It is also our practical experience in the last 18 years of hardened structures design and construction that all the above statements were proven wrong. The only real solution to providing adequate protection to a structure is to implement cost-effective protection and hardening measures. The cost effectiveness of the hardening measures can be expressed as a relationship between the cost of expected damage and the cost of the hardening measures. On one hand, investing nothing in hardening could lead to very high damage in the event of an attack. On the other hand, putting no limit on the costs of the hardening cannot ensure total protection.

The most cost-effective hardening measures are those that will provide a relatively low expected damage for minimal investment. It is the designer's task to plot expected damage against hardening costs. The client will find this data useful in re-evaluating the level of protection selected earlier in the program. Also, similar plots can be prepared for the other elements of the total protective design concept such that the client can decide where additional investment is most worthwhile; i.e., structural, electrical, mechanical, surveillance, etc. Our practical experience is that by using the above approach the client is made aware of the cost effectiveness of the protection and hardening measures and that in actual completed projects the additional costs of the hardening measures were very reasonable.

Finally, we would like to note that, in our practical experience, the most cost-effective solution differs from project to project and, therefore, this analysis should be performed for each specific project.

## DESIGN GUIDELINES AND REQUIREMENTS

A sound design basis is a basic requirement for every successful project. A comprehensive set of technical requirements should be either provided by the client, or the designer should assist the client in the development of these requirements.

The technical requirements should address all the design disciplines and basically include the following subjects:

A. <u>Architectural</u>

1. Site Planning

   - Type and location of access points to the site.

   - Type and location of perimeter physical barriers and obstacles.

   - Location of structures relative to the perimeter.

- Arrangement of outdoor areas relative to the structures and the perimeter.

- Use of landscaping in providing additional protection to the structures.

- Arrangement of the structures and their entrances and exits to conform with the functional requirements and to provide adequate relative shielding and easy escape routes.

2. Functional Design of Structures

   - Preferred internal functional arrangement in a "security-oriented" design.

   - Preferred entrances configuration including access control and anti-intrusion considerations.

3. Detailed Design

   - Location and types of security doors.

   - Location and types of windows, ventilation openings, pipes, cable penetration, etc.

   - Preferred construction materials.

   - Acceptable finishes.

B. Civil/Structural

1. Approved construction materials.

2. Minimum hardening requirements such as concrete strength, reinforcement amount and arrangement, steel types, etc.

3. Special loads for the structural design induced by the car-bomb effects.

4. Preferred structural schemes.

5. Acceptable calculation methods for dynamic blast loads.

6. Preferred construction methods and details.

C. Mechanical/Electrical

1. Preferred types of security systems and their incorporation in the structure's electrical and mechanical systems design.

2. Preventive anti-intrusion devices at all openings for electrical and mechanical systems.

3. Requirements for power supply and other electrical/mechanical subjects required during an emergency (fire fighting, smoke and gases protection, communications, etc.).

In practice, we have seen attempts by clients to issue general standard requirements for implementation on many projects of similar nature on different sites and sometimes even in different parts of the world. Although the trend to standardize is generally positive, our practical experience has shown that protection and hardening measures optimally suited for each structure are different due to specific local conditions on each site. Therefore, in cases where general standard requirements are used, we often find ourselves working on "exception to the rule" solutions trying to relate to the standard generalized set of requirements--in actual practice doing a nearly complete separate job on each site. We have found it helpful to compile and provide to A/Es a general guideline manual which contains explanations on relevant aspects but allows the A/E the freedom to provide the design which is optimal for each specific project.

## DESIGN REVIEW

As the design of hardened structures to withstand car-bomb attacks includes very specialized expertise in the subjects of weapons effects, structural dynamics, materials behavior under severe loadings, special design concepts and construction methods, etc., it is very difficult for an A/E to remain current in all of the above fields.

Internationally, it has become common practice for clients to retain a specialist consultant whose function is to assist the A/E during the design stage with the implementation of the technical requirements. This specialist consultant is also responsible to the client for approving the design from a hardening and protection point of view.

## CHANGES DURING CONSTRUCTION

In our practical experience, we found that some changes to the design are always proposed during construction due to either specific site conditions or to contractor working procedures.

Following, are two typical examples of changes proposed during construction:

- Although the design specifies that blast doors must be placed in their position before casting the concrete wall, the contractor proposes to cast the wall first, leaving an empty space for the blast door. The door, its frame, and some surrounding concrete will be placed later.

- Although the design specifies that the structural concrete elements should be monolithically cast in situ, the contractor proposes to execute them with precast elements, especially in projects where quick construction is needed.

In both of the above cases, we have nearly always found that the supervising engineers on site would allow the contractor to change the design and execute the above elements according to his proposal because this is quite acceptable in normal structures. However, in both of these cases, the resistance of the elements to the blast effects would be significantly reduced by changing the construction procedure. Clients have found it prudent to retain the design professional with knowledge of the hardening requirements to monitor construction. In this manner, the contractor's proposals can be effectively evaluated. Furthermore, strengthening methods may be proposed to the contractors which would make the suggested change acceptable; for example, special joint details for precast elements and special construction joint strengthening in the case of the blast doors.

## PROTECTION AND HARDENING OF EXISTING INSTALLATIONS

Obviously, incorporation of protective design requirements into the design of new structures or facilities is more readily accomplished than the requirement to strengthen existing structures and installations to withstand the effects of car bombs. In most of the cases, these structures are normal designs and not hardened. These situations present the ultimate challenge to the design professional and there is no limit to the innovative and creative spirit of the designers to solve the seemingly insolvable problems for existing structures.

We can state based on our practical experience with this subject, that strengthening existing weak structures to withstand car-bomb attacks is feasible, although more difficult and more expensive than in the case of new structures.

## CLOSING REMARKS

Although many structures have been designed and built worldwide to withstand car-bomb attacks it is most difficult to find their detailed

description and especially the defined threats, the protective criteria and the design considerations. There are many obvious reasons for scarcity of this type of detailed information.

The confidentiality of clients and their projects, the sensitivity of the functions of the installations and the design details are but a few of the many valid reasons clients must have a great deal of confidence and trust in their relationship with the design professional. These are also reasons why we cannot describe in this paper any actual hardened structures.

To summarize some of the benefits of our experience without compromising the client-consultant relationship, we have attempted to organize and publish what we have found to be the basic elements of the protective design process. As members of this design community we offer our opinion of this process for use by clients who have unfortunately been drawn to the conventional weapons effects arena.

# Protection of Buildings from Terrorist Attack: Design Considerations

by

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## Introduction

The use of terrorism as a mode of warfare is unfortunately becoming increasingly evident throughout the world due to the number and intensity of attacks. A favorite target of terrorist groups is U.S. Government or military buildings because they are a symbol of our country and because they are not usually designed to withstand the effects of terrorist weapons. An urgent need exists for methods of designing more survivable buildings or upgrading existing ones. Recognizing this need, the U.S. Army Corps of Engineers, responsible for the design and construction of many of these facilities, began a research program last year at the USAE Waterways Experiment Station (WES) to identify, develop, and verify procedures for designing and upgrading conventional military buildings to increase their survivability to the effects of terrorist weapons. The following general discussion is based on this research.

## Preparation

Before the design process begins much preparation is needed not only in determining the building's operational requirements but also the threat to the structure. This means determining the likelihood of the building or building components coming under attack, the types of weapons likely to be used, the likely attack directions, and the acceptable level of damage. Most of this information should be supplied by the user with guidance from the designer. For example, if a building is to be situated in a high risk area close to public streets, providing total building protection to a large vehicle bomb may be impractical. Instead, the designer may suggest that another site be considered or that key assets be located in a special hardened section of the building and that damage to the rest of the building be accepted.

## Design Philosophy

The goal of the designer is to provide protection to personnel and possibly material housed in a structure from the effects of various terrorist weapons without transforming those structures into what may be called fortifications. That is, total protection from all attack scenarios will seldom be achievable or desirable. In this regard, a large degree of damage to the structure itself may be allowed in the design so long as that damage does not affect the survival of the building occupants. In fact, allowing for large plastic deformations in some building components is a good method for absorbing the energy of a blast load. However, these should be ductile rather than brittle deformations to prevent catastrophic type failure of building components.

The user and designer should realize that physical design alone cannot provide a solution to the problem. Operational security measures, especially good perimeter security, must also be implemented to keep the attacker from gaining access to the building closer than a design standoff.

## The Threat

Weapons available to terrorists could conceivably contain all those in the inventory of any armed force in the world plus a myriad of homemade devices. However, from a somewhat historical perspective, the types of weapons likely to be used fall into four categories: small arms, man-portable rocket launchers, mortars, and bulk explosives. Of these, mortars and bulk explosives are the most serious threat from the standpoint of building damage. Providing protection against them will usually govern the design. The first three weapon types can all be used to engage the target from a remote point. Bulk explosives generally must be brought close to the building or the site perimeter to be effective.

## Perimeter Security

Even the best designed building offers no protection if the terrorist is allowed to enter the structure undetected and detonate a bomb inside. For this reason perimeter security is of utmost importance. Perimeter security consists mainly of barriers or obstacles around a building to prevent or impede access by unauthorized personnel coupled with a well trained and protected guard force to control access and respond to an attack. In the case of vehicle bombs, perimeter security provides the standoff that is so essential in reducing the blast load. Opaque fences can also be used to limit observation of the facility. This may deny an attacker with small arms or shoulder-fired rockets from engaging his target. Various commercial products ranging from fences to mechanized vehicular barriers are available in this area. Although not all have been tested, performance data are available on some of the products. Reference 1 gives the performance of various types of barriers in delaying penetration by various attack methods, while Reference 2 is a recent assessment of vehicular barriers. Finally Reference 3 presents designs for access points to a facility and discusses the relative costs and performance of several vehicular barriers.

## Site and Building Planning

Another area which can be used to increase building survivability other than the structural design itself is proper site and building planning. This includes making use of terrain and vegetation to help provide perimeter security (e.g., creeks and drainage ditches may be good vehicle barriers and trees may limit observation). In some cases, terrain features may be used to limit possible attack directions so that hardening of the structure can be limited to certain areas. Building location is important. Buildings should be set back as far as possible from the perimeter and oriented to reduce reflected blast loads. If the site is large enough, dispersing functions into several buildings instead of one may also help. Camouflage and deception can also be employed. Building geometry is important. For example, reentrant angles should be avoided. The interior plan of the building is important. For example, if the attack can be limited to only one direction, the building

plan should have low density personnel functions along that side, i.e., hallways, storage areas, etc. The reader will note how this aspect of the design ties in closely with a good threat definition.

Ballistic Protection

Damage to a building from small arms is generally limited to highly localized failure of material versus structural damage. Protection is likewise dependent mainly on the mass density of the material the bullet strikes. Data and analysis procedures on the penetration of various small arms into standard construction materials can be found in numerous sources (References 4 - 6, for example). More research is being planned for this area for penetration into spaced construction materials. Various commercial products are also designed specifically for ballistic protection such as special steel armors and bullet-resistant glass. Thus the designer has mainly to choose the material, its thickness, and where it is to be installed, and then design structural supports for it. Ballistic protection is also a feature that can be provided to a certain extent as an add-on to existing buildings. The design for ballistic protection should be checked for conflict with other aspects of design. For example, a steel armor plate, although supported enough for bullet impact, may become a hazardous projectile itself if it is not supported adequately against a blast loading.

Rocket Protection

This threat consists mainly of shoulder-fired rocket grenades primarily developed for use against tanks and other heavily armored vehicles. They can penetrate several inches of armor and thus can defeat most standard construction materials and thicknesses. As with small arms, damage is usually limited to the localized area where the grenades penetrate. Defense against this type of attack is usually accomplished by using a sacrificial wall or screen which causes the round to detonate before impacting the main structure. This degrades its penetration capability (see Reference 5, for example). Sometimes the perimeter security fencing or barriers can be used as a screen as can highly specialized armors are also capable of defeating this threat.

Mortar Protection

Mortars are indirect fire weapons (as opposed to direct fire small arms and rockets) and may be used to attack a building from a remote location. Generally inaccurate, they can contain a substantial amount of high explosive in a fragmenting case and can be very damaging if they score a direct hit on the building or land fairly close to it. This type of attack is currently being used frequently in Northern Ireland. Protection is provided by designing the building walls and roofs to take the impact and blast and fragment loads directly or by providing sacrificial roofs and walls (especially on the ground floor). Research is being conducted to gather data and develop design procedures for the response of masonry and reinforced concrete walls to this type of threat. Current appropriate methods can be found in such documents as References 7-9. Windows are among the building elements most susceptible to blast and fragment damage from mortars. They typically will withstand much less of a load than the building wall and when they fail the produce potentially injurious glass shards. Protection for

windows can be provided directly by designing them and their mountings to withstand a load without failing, by using plastic film adhered to the interior of the window to retain the glass fragments when failure occurs, or by eliminating them from the design altogether. There are several manufacturers of blast-resistant windows. Reference 10 is an excellent recent source on the design of blast-resistant windows.

## Bomb Protection

The bomb threat consists mainly of some quantity of bulk high explosive or homemade explosive positioned near a building (e.g., via a parked vehicle) and then detonated remotely or with a time delay mechanism. In some cases (most notably, the embassy bombing in Beirut) the vehicle will try to gain access beyond the perimeter security by forced entry through the entry points to the installation. It is for this threat that perimeter security plays such a vital role by ensuring a standoff distance between the bomb and the building.

On detonation of the bomb, the explosive charge releases gases which expand rapidly outward, compressing the air in front of the gases into a shock wave. The shock consists of an abrupt rise in pressure followed by a return to atmospheric and then a slow drop to below atmospheric pressure followed by a return to normal. When the shock or blast reaches a wall lying across its path, it is reflected and the pressure on the wall is increased to several times that of the incoming wave. The duration of this reflected pressure is on the order of milliseconds. Damage to a building can include window breakage, failure of exterior and interior walls or cladding, and failure of the building frame. The following approaches are used for a building design to provide for bomb protection:

(a) Provide a large enough standoff using perimeter security to reduce blast loads to a level below that recommended for conventional inhabited buildings. These distances are given as a function of explosive weight in Reference 11 and have been determined as safe distances for explosive manufacturing and storage.

(b) Provide a blast wall or barrier between the bomb and the building to reduce the building loads. This technique works, but the amount it reduces the loads is not well determined for all cases. The WES and the Naval Civil Engineering Lab are currently conducting research in this area.

(c) Design the building elements and frame to withstand the blast load. The design of blast-resistant windows is discussed in Reference 10, and the design of reinforced concrete wall panels is presented in Reference 7. Reference 12 presents a method for determining the response of masonry walls to large blast loads. The response of building frames to blast loads is discussed in Reference 13. The WES is currently conducting research in some of these areas.

## Summary

This paper presents only a few of the basic principles governing the design of buildings for protection from terrorist attacks. Some of these principles have been developed over the years for the design of structures to survive accidental explosions, conventional weapon attack, and even nuclear weapon attack. As such, test data verify their accuracy. However, there are areas

of design for which little guidance is available. This paper, therefore, is, by no means, definitive. Many other studies are being conducted in this area, and research is being conducted by the Army, Navy, State Department, and other government agencies.

## Acknowledgement

The author wishes to acknowledge the Office of Chief of Engineers (OCE) who sponsored the research program from which this paper was prepared. This work was under OCE's RDT&E Program, project 4A162719AT40, "Mobility and Weapons Effects Technology."

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# SUGGESTIONS FOR HARDENING STRUCTURES AGAINST CAR-BOMB ATTACK

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For several years now, the U.S. Air Force has made a concerted effort to increase the survivability of ground-based systems subject to attack by conventional weapons. Much of the information obtained in this effort can be applied to hardening structures against car-bomb attacks.

One finding of particular importance is how effective soil is in attenuating airblast effects produced by conventional munitions. Data from recent tests show that peak overpressures caused by airblast can be reduced by at least an order of magnitude simply by placing soil in front of a structure.

This attenuation comes from two sources. First, the soil actually lowers the peak pressures produced by the airblast. Second, the peak pressure takes longer to develop in the soil. In some cases, the structure may respond enough during this period of time (called rise time) to pull away from the soil, thus relieving the load applied to the structure by the soil.

* Funding for Captain Whitehouse's blast and shock research provided by the Frank J. Seiler Research Laboratory, USAF Academy, Colorado.

Section 5.3.2 of Reference 1 indicates the first effect is caused by the hysteretic nature of soil. This reference also reveals that the slower rise time can be attributed to the nonlinear stress-strain relationship usually associated with soils. This non-linearity forces higher pressures to travel at slower wave speeds, thereby increasing the rise time.

The benefits of load relief made possible by structural response have been known for some time. Reference 2 models soil-structure interaction using the following equation:

$$\sigma_i = \sigma_{ff} + k\,(u_{ff} - u_s) + C\,(v_{ff} - v_s) \qquad (1)$$

where: $\sigma_i$ = interface pressure (pressure on the structure produced by the soil)

$\sigma_{ff}$ = free-field stress (stress in the soil)

$u_{ff}$ = free-field displacement

$v_{ff}$ = free-field velocity

$u_s$ = structural displacement

$v_s$ = structural velocity

$k$ = spring constant used to model soil stiffness

$c$ = damper constant used to model soil damping

The relative-displacement term may not apply to the dynamic loading experienced by structures in a blast environment and will be ignored in this paper. However, the relative-velocity term seems to be very important in such environments (see Ref 3). The damping constant is usually given by

$$c = \rho C_L \tag{2}$$

where $\rho$ = mass density of soil

$C_L$ = loading wavespeed of soil

If Equation (1) is a valid model for soil-structure interaction, it indicates that interface pressures will be less than free-field stresses if the structure acquires more velocity than the soil.

The equation also shows that interface pressures can be greater than the free-field stresses if the structure moves more slowly than the soil. The limiting case is no structural motion which produces an interface pressure of

$$\sigma_i = \sigma_{ff} + \rho C_L v_{ff} \tag{3}$$

On the wave front of a uniaxial wave, $\rho C_L v_{ff}$ is equal to $\sigma_{ff}$. Therefore, if the structure does not move, the interface pressure is twice the free-field stress, which is consistent with what wave mechanics reveals about wave reflection at a rigid boundary.

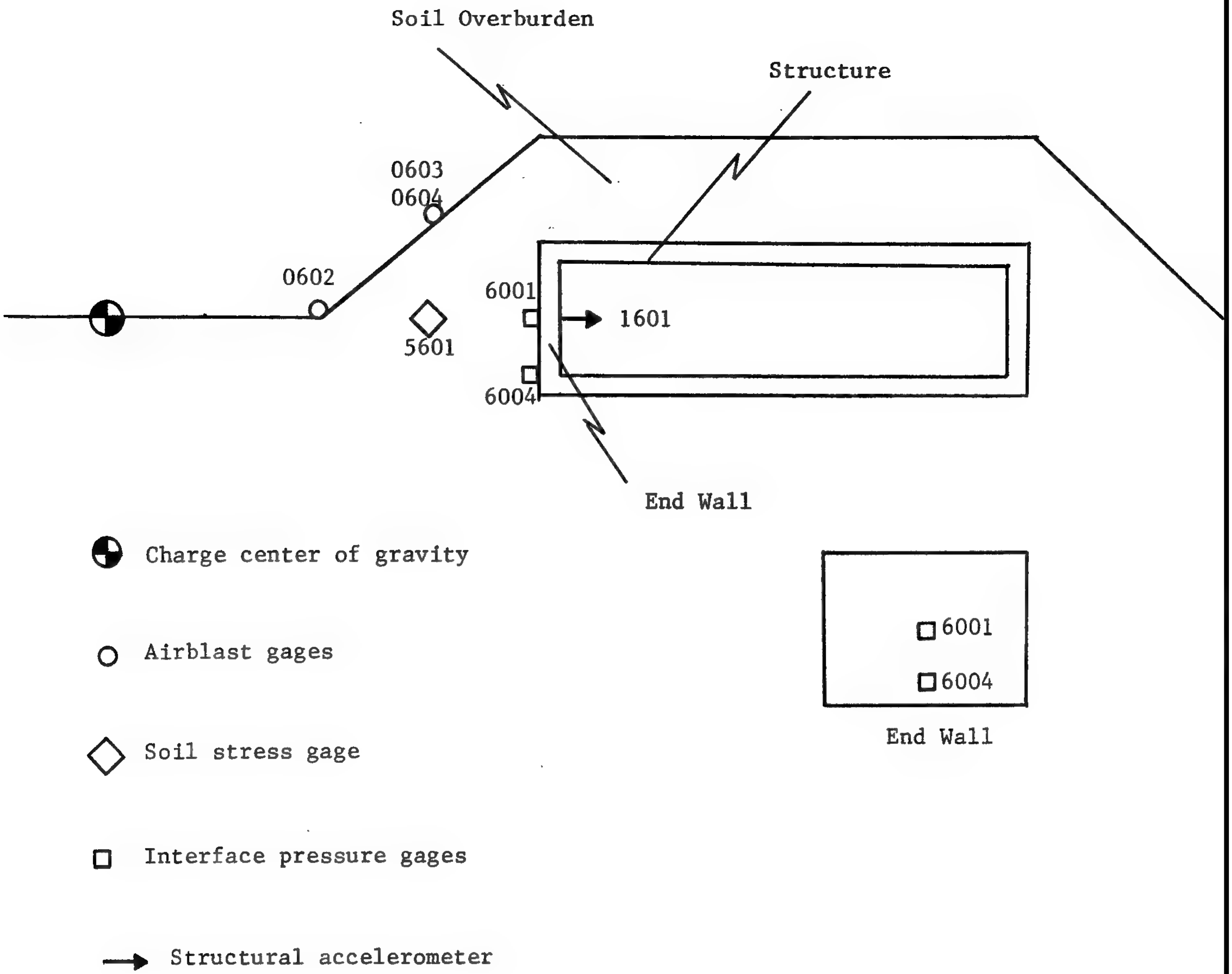



Figure 1. Test Configuration for MUST-IIB

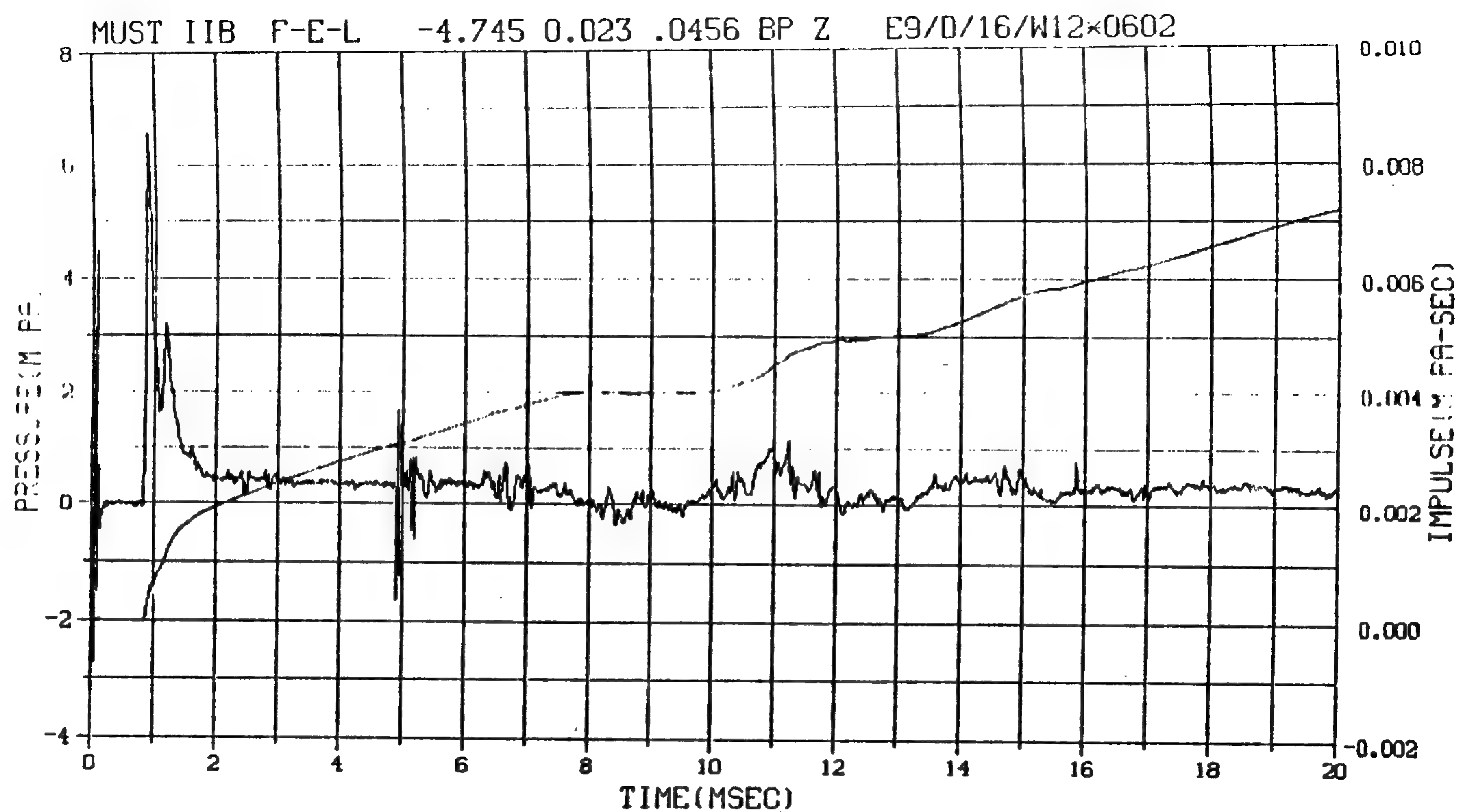



Figure 2. Airblast Data from Gage 0602

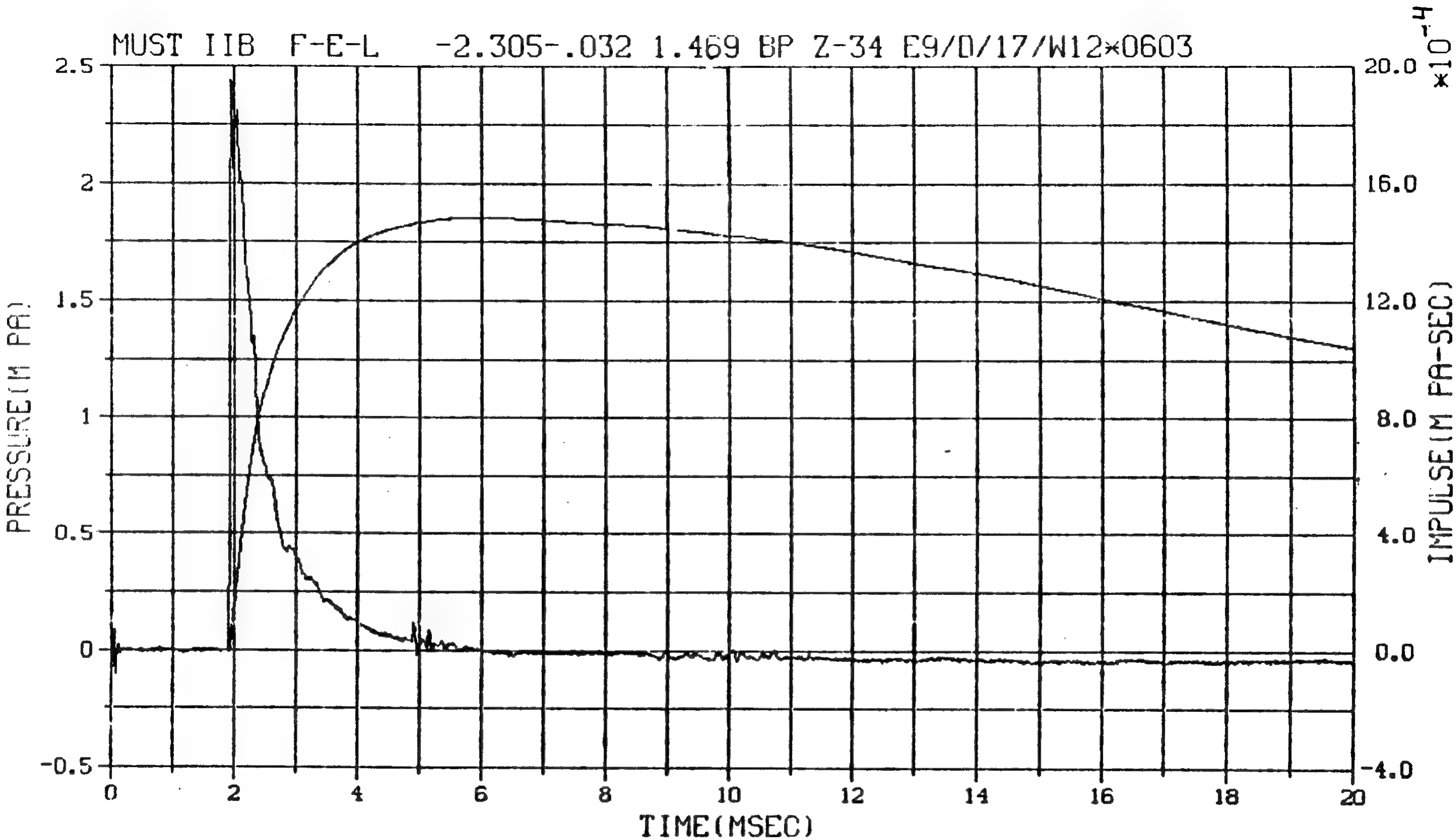
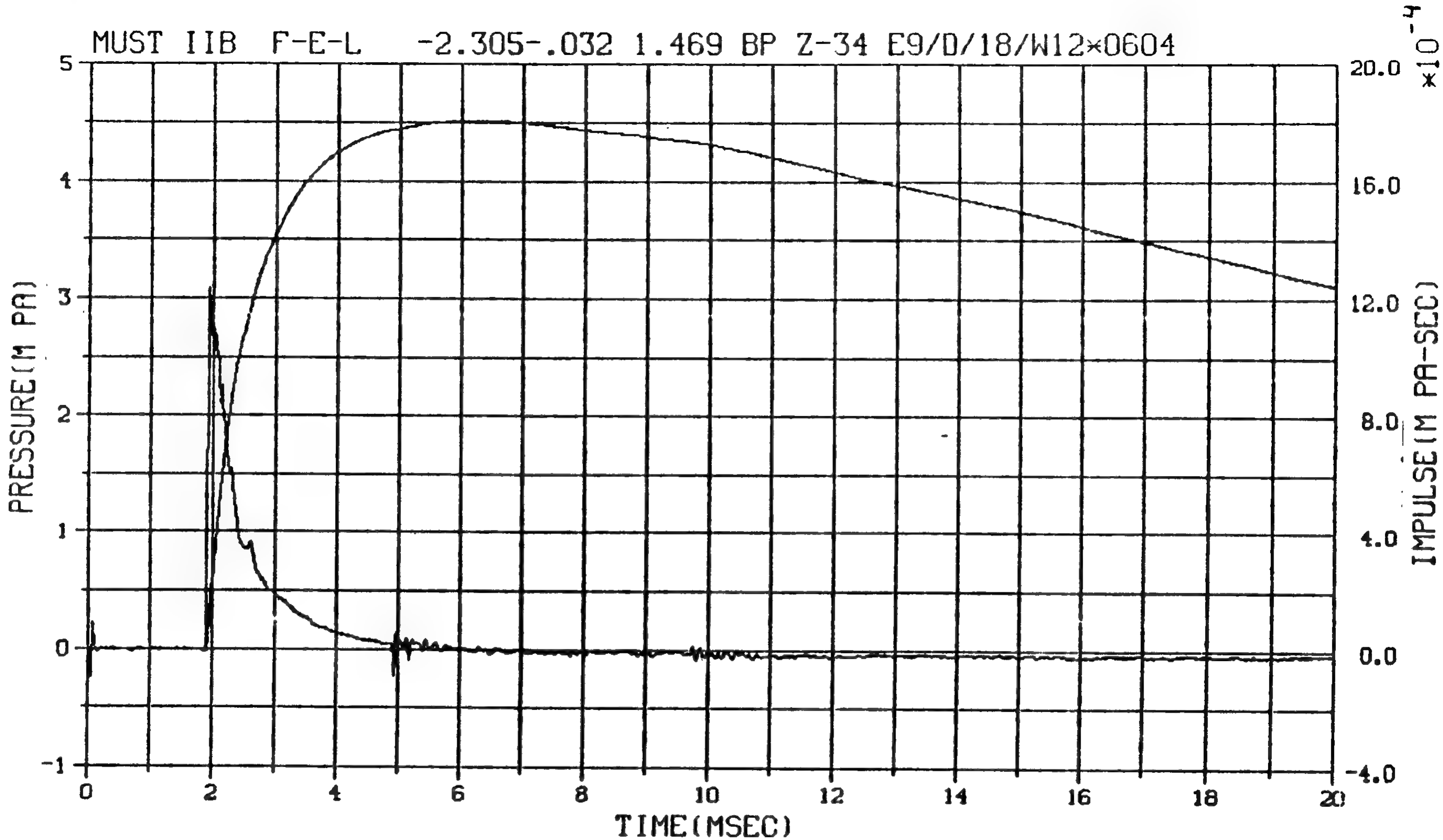



Figure 3. Airblast Data from Gage 0603




Fiture 4. Airblast Data from Gage 0604

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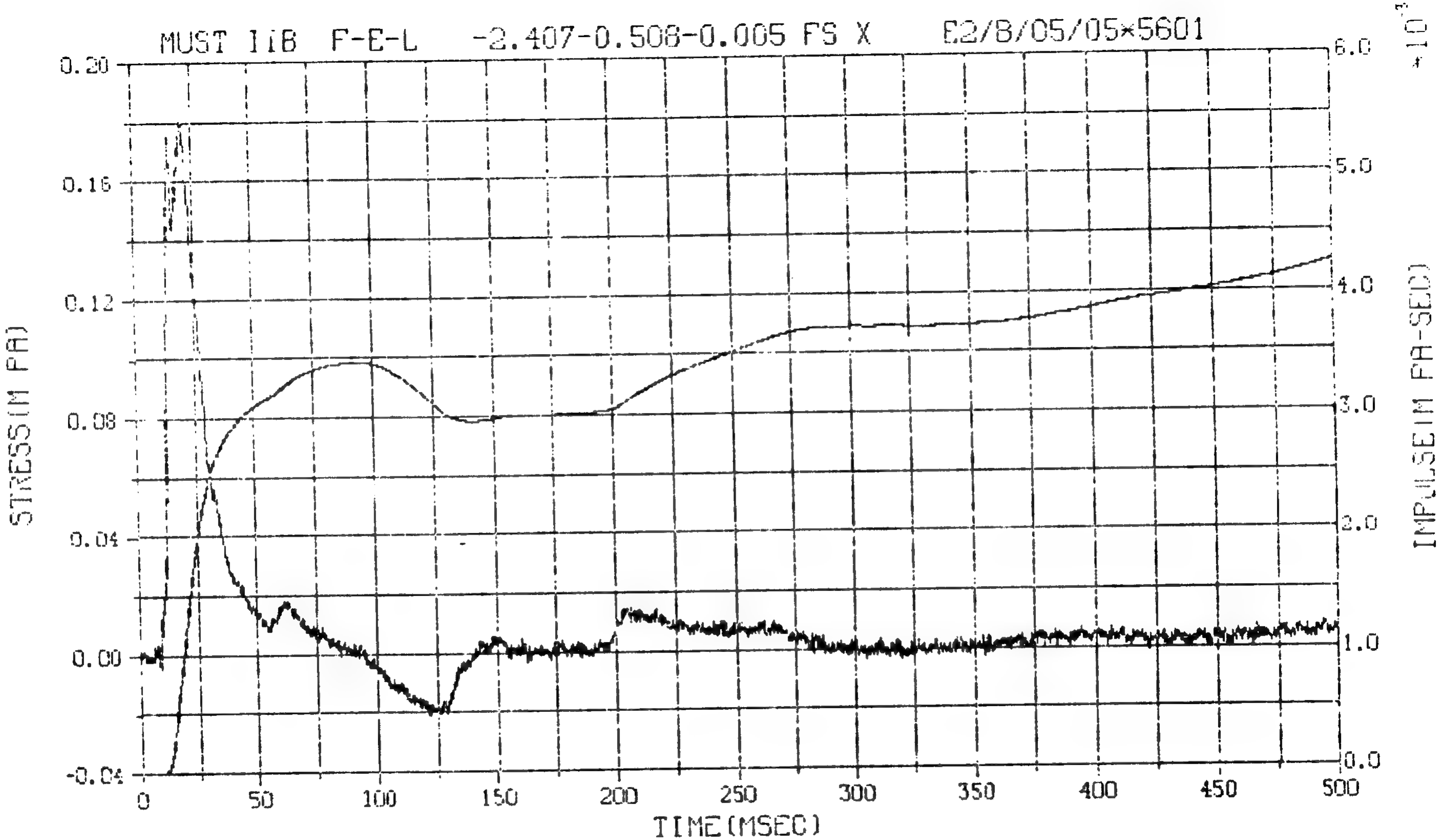


Figure 5. Soil Stress Data from Gage 5601

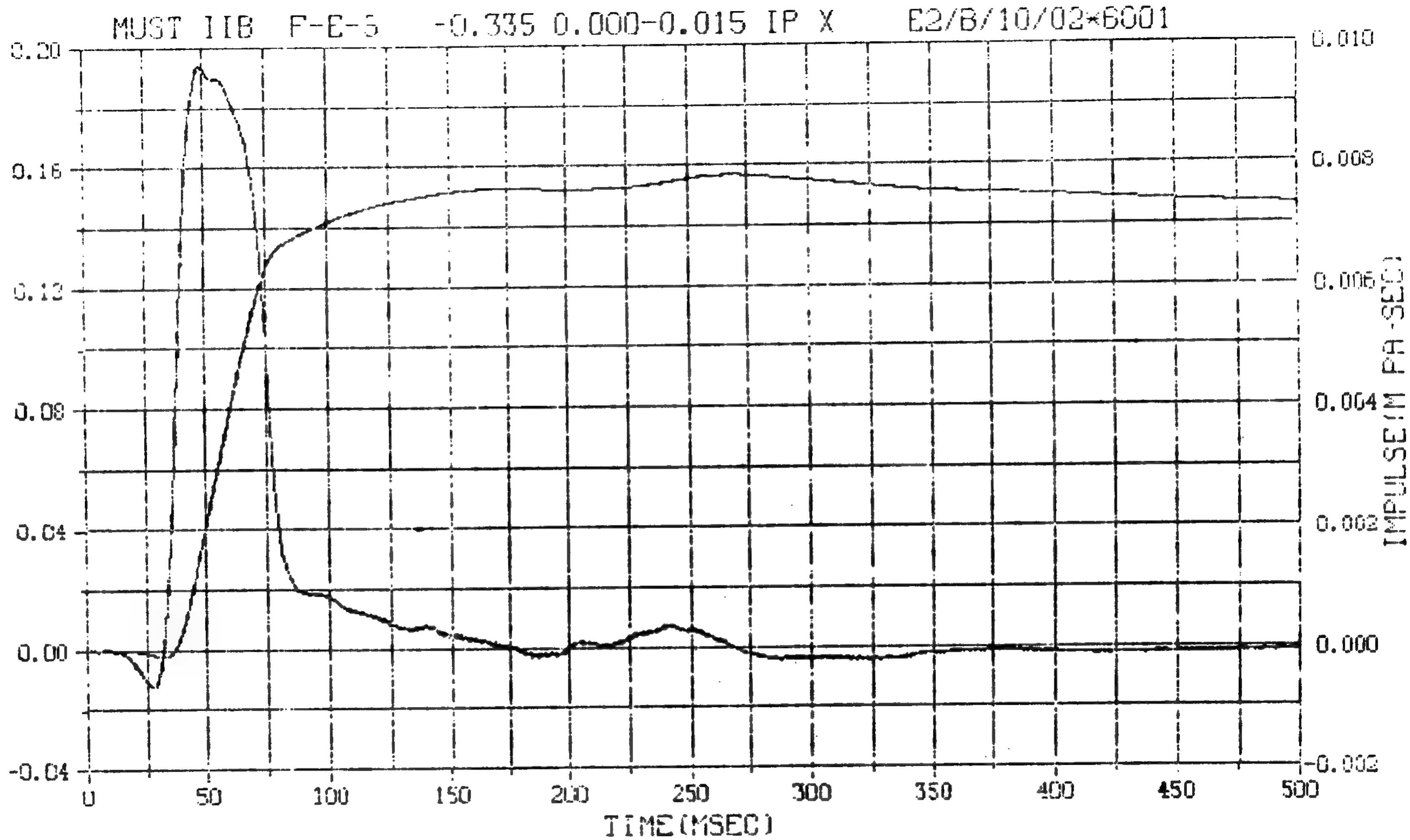


Figure 6. Interface Pressure Data from Gage 6001

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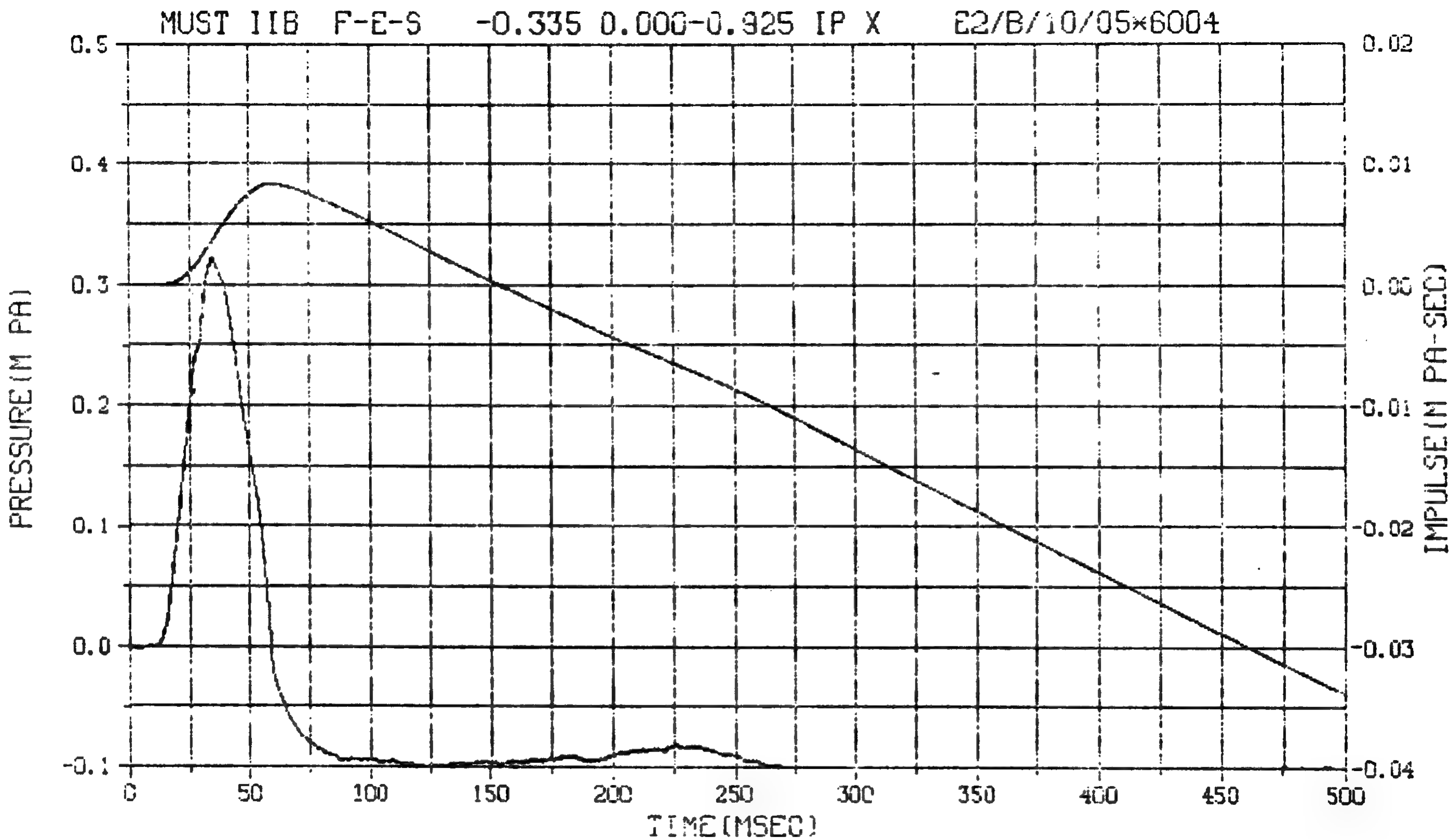



Figure 7. Interface Pressure Data from Gage 6004

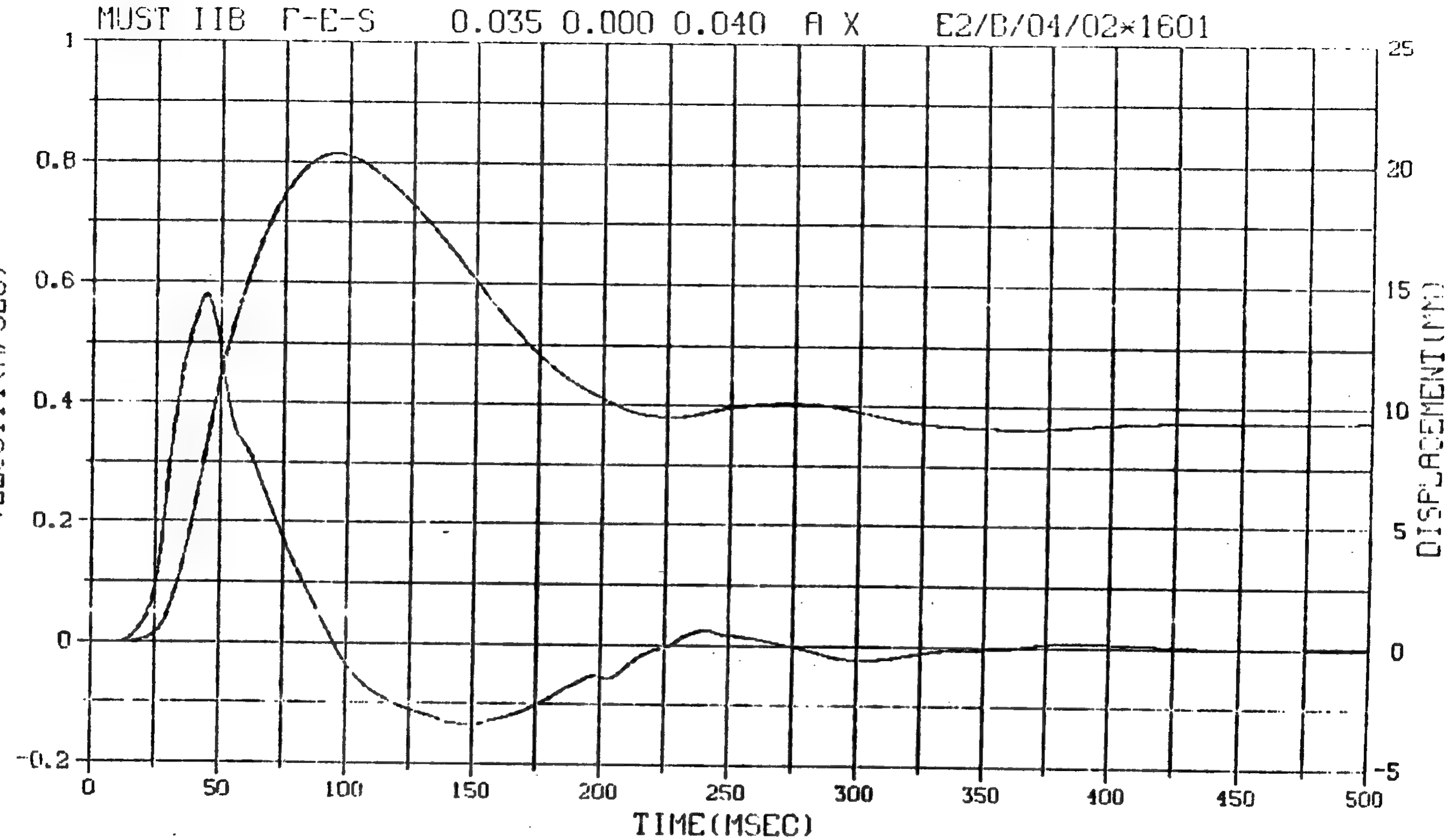



Figure 8. Structural Velocity Data from Gage 1601

The important facts to keep in mind about this discussion are that soil lowers the overpressures caused by airblast and the soil also increases the time required to obtain the peak overpressure. If this rise time is long enough, the structure's response may relieve the loads already reduced by the soil. Neither of these effects is possible without the soil.

These effects are apparent in the data seen in Figures 1-8. Figure 1 illustrates the configuration of the test from which the data were obtained.

Figures 2-4 show the airblast overpressures measured on the soil overburden. The peak pressures range from 2.4 MPa (350 psi) to 6.6 MPa (960 psi), and these peaks develop almost instantaneously. The max rise time is on the order of 0.1 milli-second (ms), certainly not enough time for structural response to cause any load relief.

As can be seen in Figure 5, the soil reduces the peak overpressure significantly and increases the rise time. The peak pressure of 0.18 MPa (26 psi) is less than three percent of the 6.6-MPa (960 psi) peak pressure recorded on the overburden. In addition, the rise time is on the order of 8 ms rather than 0.1 ms.

Figures 6 and 7 show the interface pressures measured on the structure. The initial negative pressure seen in the data from gage 6001 indicates this gage may have pulled away from the soil before registering any pressures. This motion may have been caused by a structural response induced by vertical loading at the top of the structure which arrived before the horizontal loading reached the structure's end wall.

Other than this anomaly, the pressures recorded by these gages seem to be consistent with the conclusions drawn from Equation (1). The peak pressure of approximately 0.2 MPa (29 psi) at gage 6001 is lower than the 0.32-MPa (46-psi) pressure recorded by gage 6004. Gage 6001 was mounted on the center of the end wall and gage 6004 was located near the bottom of the wall. Therefore, the lower pressure at gage 6001 is attributed to greater load relief made possible by the greater motion experienced at the center. Both of these peak pressures are higher than the 0.18-MPa (26-psi) peak pressure measured in the soil indicating the structure may not have moved faster than the soil, but the peak pressure still remained below the peak reflected pressure of 2 $\sigma_{ff}$ expected at a rigid boundary.

Figure 8 shows that the center of the end wall did experience some motion while the structure was loaded. This motion was probably responsible for reducing the pressures experienced in the center of the end wall.

Comparing Figure 2 with Figure 7 reveals that soil can reduce airblast pressures by as much as 95 percent. The increase in survivability afforded by this drastic reduction in pressure can be obtained with fairly modest amounts of soil. Figure 9 shows one possible soil configuration which should be effective in attenuating airblast overpressures. This recommendation is based on testing done in sandy soils. Clays, and particularly saturated clays, may not enhance survivability as well as sand. Therefore, only sand is recommended for the berm material. The 1-to-3 slope is recommended for stability, plus a lower slope reduces the peak pressures generated on the berm by the airblast.

The data shown in Figures 1-8 were obtained in the Multi-Unit Structure Test (MUST) series performed by the Civil Engineering Research Division of the Air Force

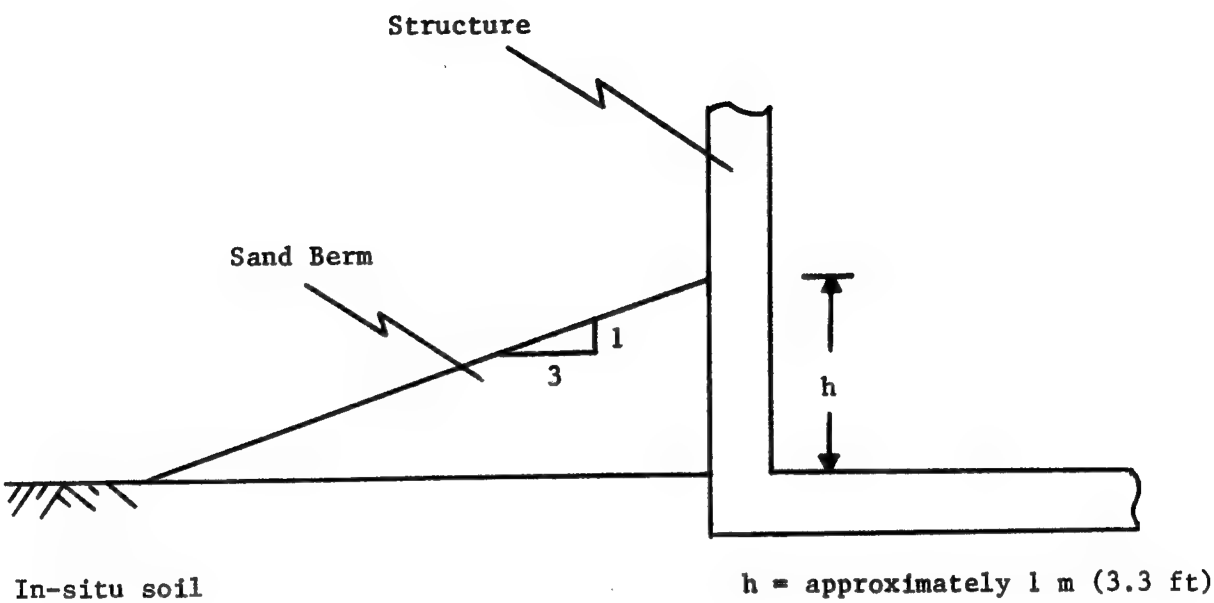



Figure 9. Recommended Soil Configuration

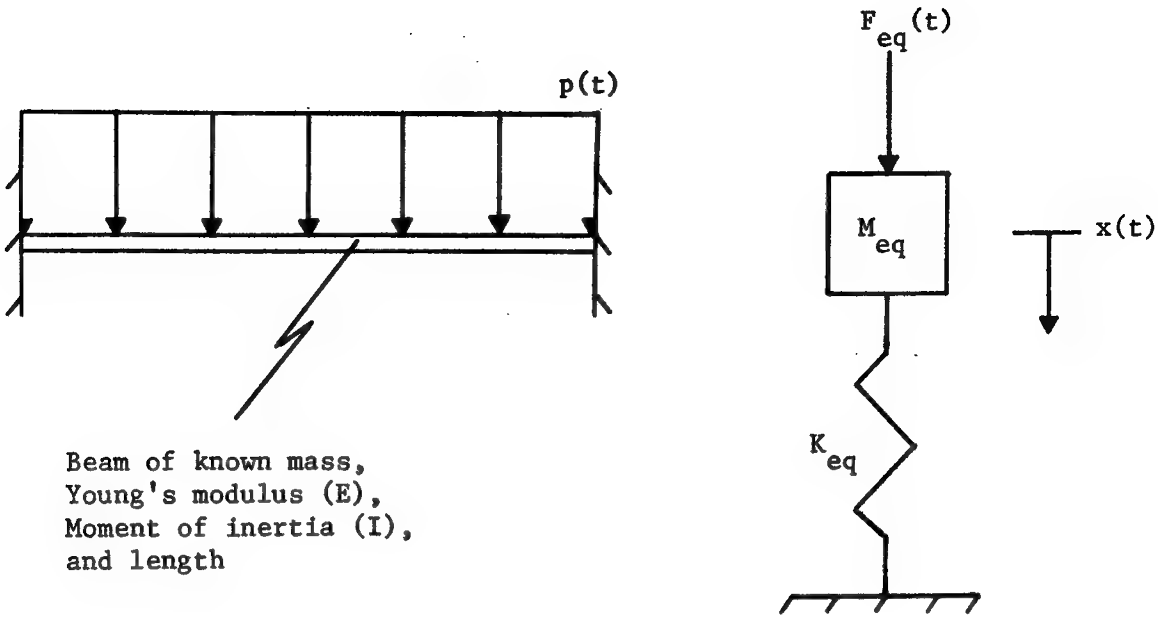
Weapons Laboratory (AFWL/NTE) at Kirtland AFB, NM. These tests were funded by the Aeronautical Systems Division (ASD) at Wright Patterson AFB, OH. References 4-10 provide more data obtained from this series.

The Meppen Wall Tests conducted partially by AFWL/NTE in Meppen, Germany, investigated simple methods for increasing structural hardness. In addition, the Conventional High Explosive Blast and Shock (CHEBS) test series has done much to characterize weapon effects produced by general-purpose bombs. Details on these tests can be obtained by contacting Dr. Maynard A. Plamondon, the Division Technical Advisor for AFWL/NTE (505-844-9008, AV 244-9008).

Many other tests have been conducted by the Air Force's Armament Division (AD) and Engineering and Services Center (AFESC). Information regarding these activities can be obtained from Mr. John R. Hayes, Jr, the Senior Scientist for AFESC (904-283-6451, AV 970-6451).

A final comment regards the use of analytical tools for designing or analyzing hardened structures. The use of sophisticated analytical tools cannot be justified if large uncertainties are present in the problem. Given the vast uncertainties associated with defining car-bomb threats, current design and analysis efforts should use only simple structural-dynamics models. In particular, the single-degree-of-freedom (SDOF) model discussed in section 9.2 of Reference 1 should be adequate for most calculations of interest at present.

Figure 10 gives one example of a SDOF model. The original system is a fixed-fixed beam subjected to a uniform load which varies with time. The response of this system can be modeled by a SDOF system where $M_{eq}$ and $K_{eq}$ account for the




$p(t)$ = distributed dynamic load

$F_{eq}(t)$ = equivalent dynamic load

$M_{eq}$ = equivalent mass

$K_{eq}$ = equivalent stiffness

$x(t)$ = response of SDOF system

Figure 10. Example of an Equivalent Single-Degree-of-Freedom (SDOF) System

inertia and stiffness of the beam, respectively, and $F_{eq}$ accounts for the dynamic loading.

$M_{eq}$, $K_{eq}$, and $F_{eq}$ can be found only after assuming the beam deflects in a particular shape called the mode shape. This shape usually corresponds to the deflection associated with the beam's fundamental mode of vibration or its shape under static loading which has the same spatial distribution as the dynamic load.

The response of the SDOF model corresponds to the motion of the point on the beam that experiences the max deflection, which is the center for the beam shown in Figure 10. The stresses in the beam can be estimated knowing the response of the SDOF system and the assumed mode shape. Once again, such a model should be accurate enough for most problems involving the hardening of structures against car-bomb attack.

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CALCULATING DESIGN LOADING
FOR BLAST AND SHOCK

by
Dr. Paul F. Mlakar and Mr. William J. Flathau

In some cases, the detonation of car bombs has resulted in considerable damage to nearby structures. Thus, one facet of securing installations from such threats involves structural design against the loadings imposed by car bomb explosions. In this manuscript, we first illustrate the essential features of car bomb blast loading and structural response to this loading. Next, the calculation of statically equivalent design loadings is explained. We then show the dependence of this loading on the size of the car bomb explosion and the standoff distance from the structure. Finally, practical ways in which this loading can be reduced are discussed.

To discuss the nature of car bomb blast in structural response, consider the attack illustrated in Figure 1. The detonation of 125 pounds of TNT occurs 10 feet from a structural column whose span is 15 feet. The explosion loads the facing side of the column with a blast pressure as shown in Figure 2. Note that the blast pressure travels up the column such that only part of the column is loaded at any one time. Figure 3 shows how the column deflects under this blast loading. Observe that little deflection occurs during the time that the blast pressure actually acts on the column. The maximum response of the column happens after the blast load has ended. The reason for this lag in structural response is the mechanical inertia of the column.

In structural design codes, the effects of dead and live loadings are considered through an equivalent static loading. It is thus practically desirable to represent the complicated structural response to car bomb blast loading in this simple fashion as well. In general, this representation is a complex function of the duration of loading, the natural period of the structural element, and degree of inelastic structural response which is acceptable. To illustrate the procedure, let us consider totally elastic structural response which might be appropriate for a critical nonredundant column in a high-rise structure. Because of the lag between blast loading and structural response previously noted, one can approximately say that all of the kinetic energy initially imparted to this structure by the blast is converted to elastic strain energy as the structure deforms. In this case, a static pressure which will cause the same maximum response is given by:

$$p_s = \frac{2\pi}{T} i_{r\alpha} \qquad (1)*$$

*J. M. Biggs, 1964, Introduction to Structural Dynamics, McGraw-Hill Book Company, New York, NY.

in which $i_{r\alpha}$ is the reflected impulse or time integral of pressure and $T$ is the natural period of the structural element. The latter parameter is a function of the structure alone and is independent of the particular car bomb blast loading it. Note that for a given blast, structures with longer structural periods have a lower design loading because of their greater inertia. The reflected impulse corresponding to given car bomb detonations is obtained from Figures 4 and 5. Note that $i_{r\alpha}$ decreases with increasing angle of incidence $\alpha$. Further, as the weight of explosive detonated $W$ increases, so does the reflected impulse. Finally, $i_{r\alpha}$ decreases with increasing standoff $R$.

When this procedure is applied to real situations, significant design loadings can result. Consider the reinforced concrete column shown in Figure 6 whose cross section reasonably represents construction practice in buildings which could be targeted for terrorist car bomb attacks. If the span of this column is assumed to be 15 feet, its natural period $T$ in lateral vibration is calculated to be between 15 and 33 msec, depending on the fixity of its ends. For illustrative purposes we assume this fixity to be such that the natural period is 20 msec. Let us first consider design loadings for a car bomb equivalent to $W$ = 125 pounds of TNT. The result of Equation 1 is shown in Figure 7 for $R$ = 3-, 10-, and 30-feet standoffs from the column. For the smallest standoff, the loading is much greater in magnitude and more skewed in spatial distribution than that normally considered in structural design. However, this loading decreases sharply in magnitude and becomes more uniform in shape with increasing standoff. If the car bomb is instead the equivalent of $W$ = 1,000 pounds of TNT, the equivalent loadings of $R$ = 10, 30, and 100 feet of standoff are shown in Figure 8. It is clear that an increase in car bomb size significantly increases the design loading of a structural element.

The design loadings for car bomb attack illustrated here are much higher than those used in the structural design for other loading cases. One way of reducing these loadings is to accept some degree of permanent inelastic response when personal safety and economic costs warrant this. It has also been shown that these loadings can be significantly reduced by insuring that significant standoff from the endangered structural element exists to the point of car bomb detonation. Finally, the loading can also be reduced by considering a reasonable magnitude of car bomb explosive in light of terrorist experience.

From the foregoing, a significant increase in structural resistance beyond that required for usual loadings may be required for car bomb attack. Alternately, the car bomb design loading can be reduced by insuring a significant standoff distance $R$ from the point of detonation. A further reduction can result from a modification of Equation 1 for inelastic response if the ductility and the importance of the structural element permit this. A final decrease in car bomb design loading can occur if only those quantities of explosive $W$ are considered which intelligence estimates indicate are credible.

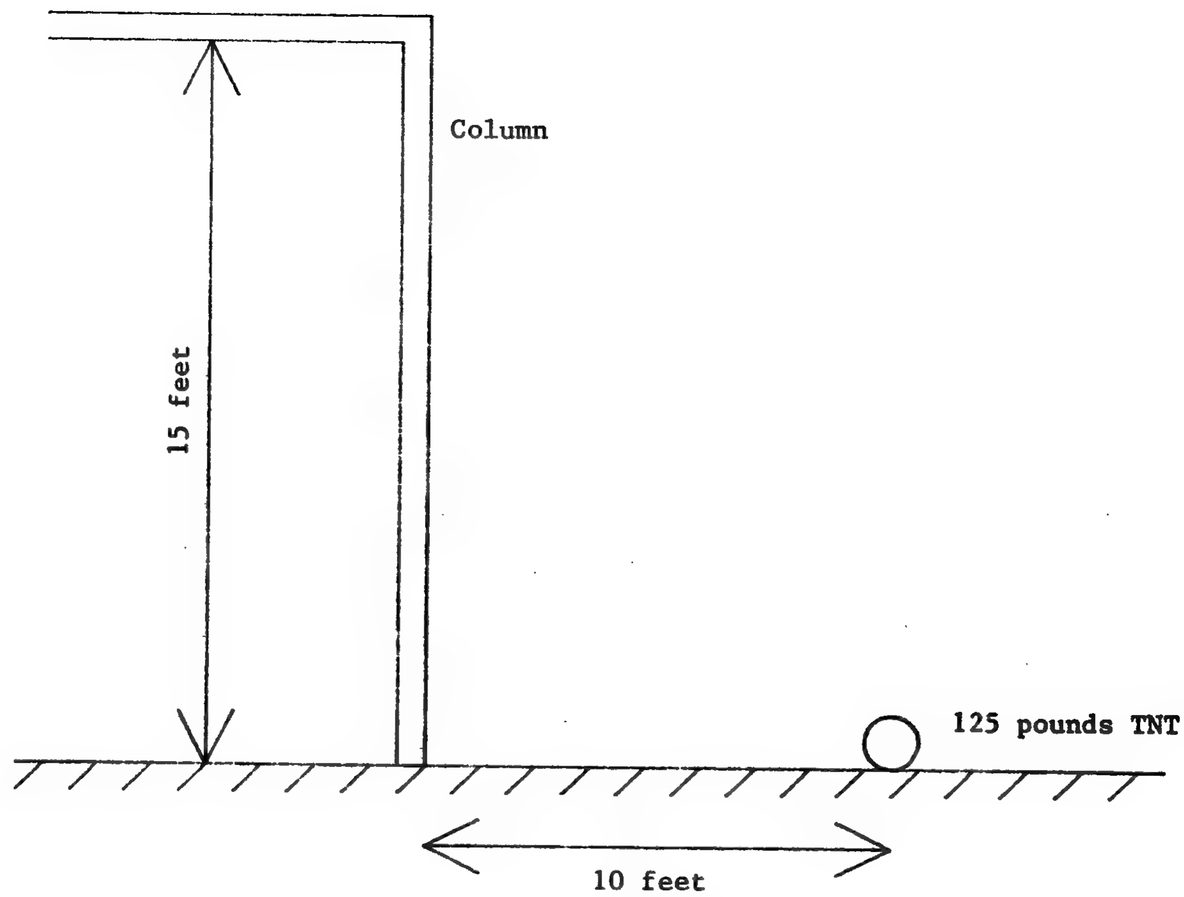


Figure 1. Car-bomb attack of structural column.

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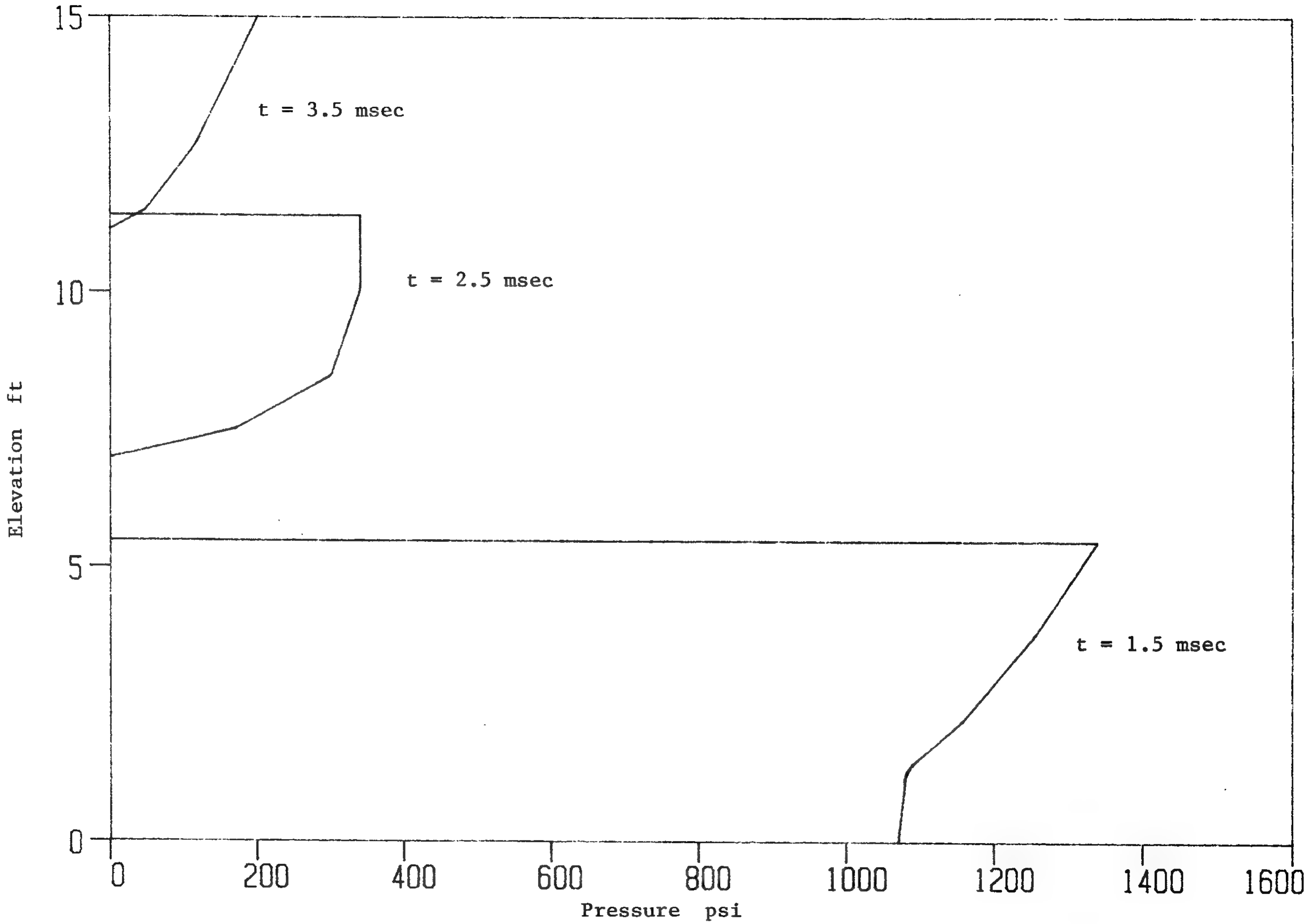


Figure 2. Loading of structural column by 125 pounds at 10 feet.

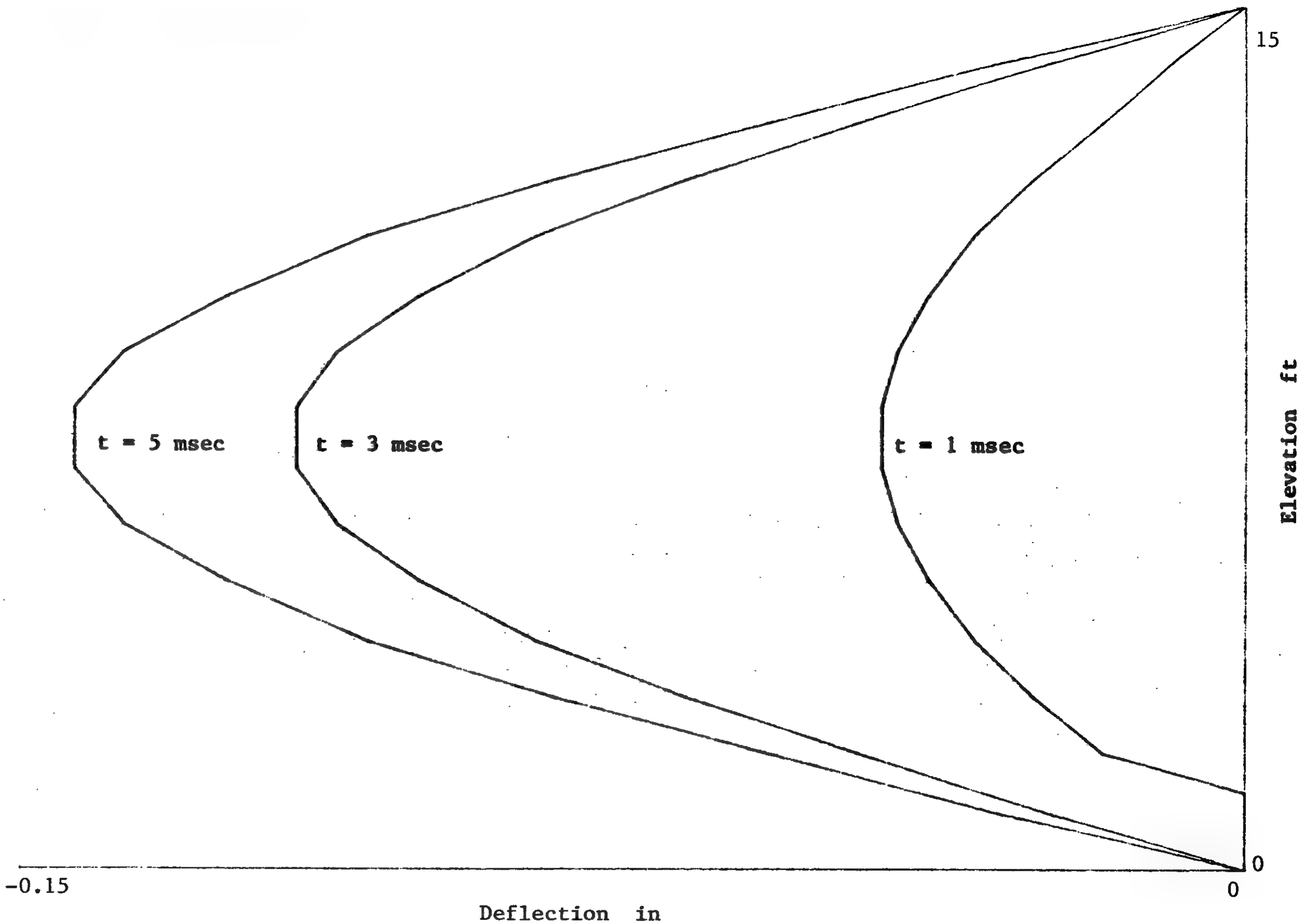


Figure 3. Response of structural column with T = 20 msec to 125 pounds at 10 feet.

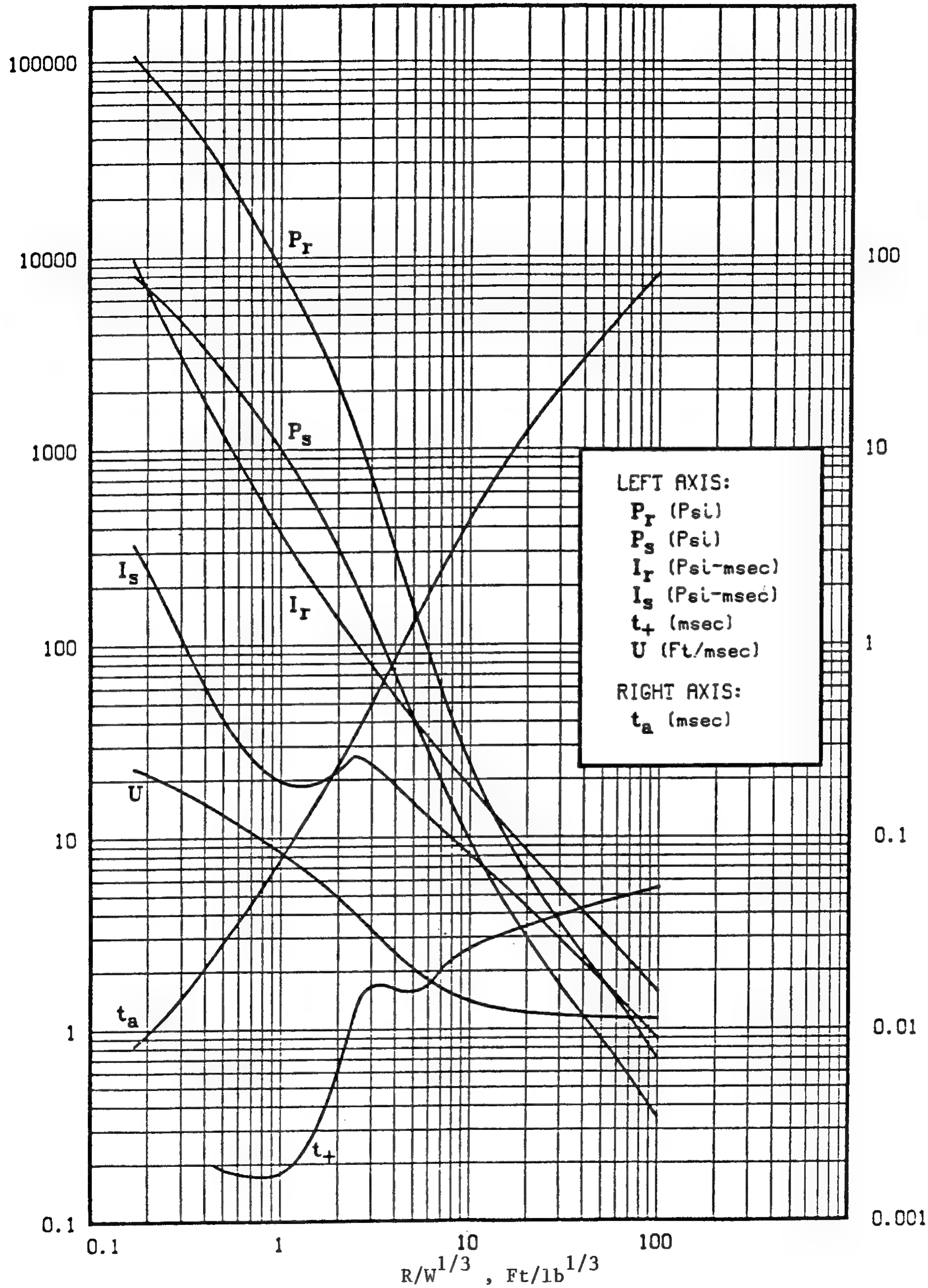


Figure 4. Airblast parameters for TNT hemispherical ground bursts (Kingery and Bulmash, 1984, "Airblast Parameters from TNT Spherical Air Burst and Hemispherical Surface Burst," Prepared under US Army Armament Research and Development Center, Ballistic Research Laboratory, Aberdeen Proving Ground, MD.)

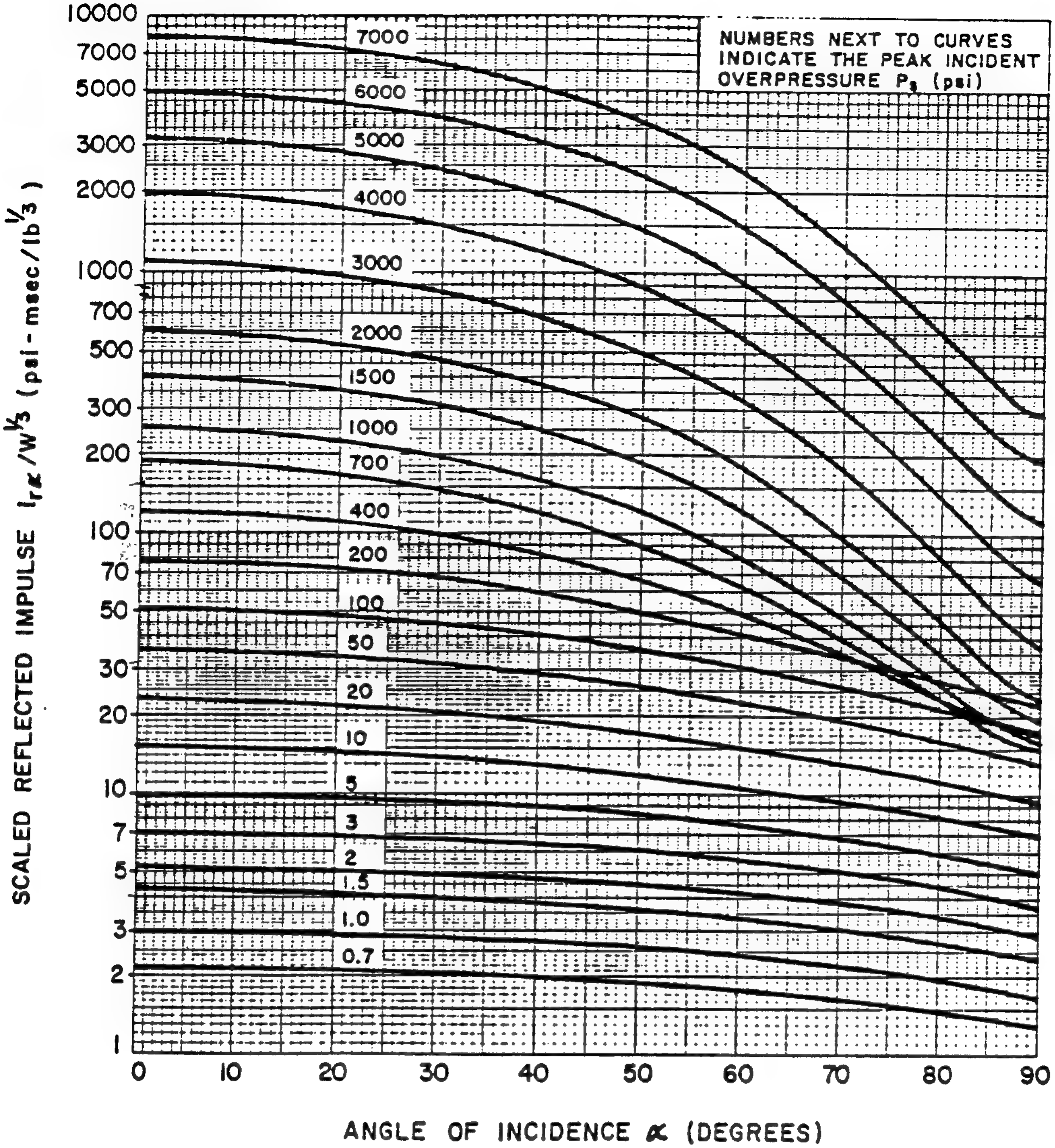


Figure 5. Obliquely reflected blast parameters (M. Dede, et al., 1985, "Structures to Resist the Effects of Accidental Explosions, Volume VI, Special Considerations in Explosive Facility Design, Report ARLCD-SP-84001, Prepared for US Army Armament Research and Development Center, Large Caliber Weapon System Laboratory, Dover, NY, by Ammann & Whitney, Consulting Engineers, New York, NY.

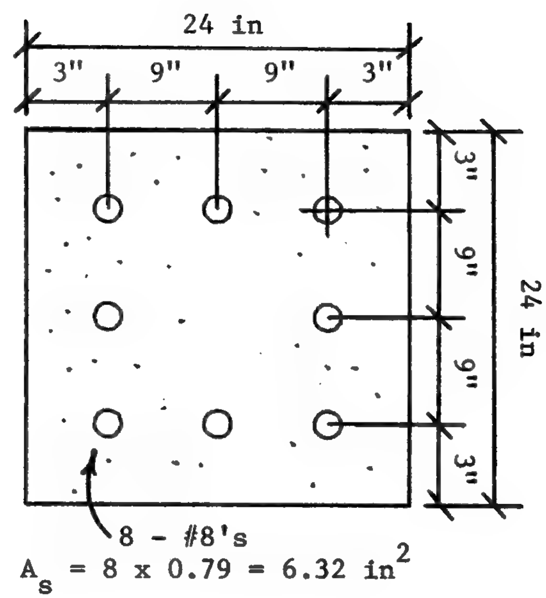


Figure 6. Reinforced concrete column.

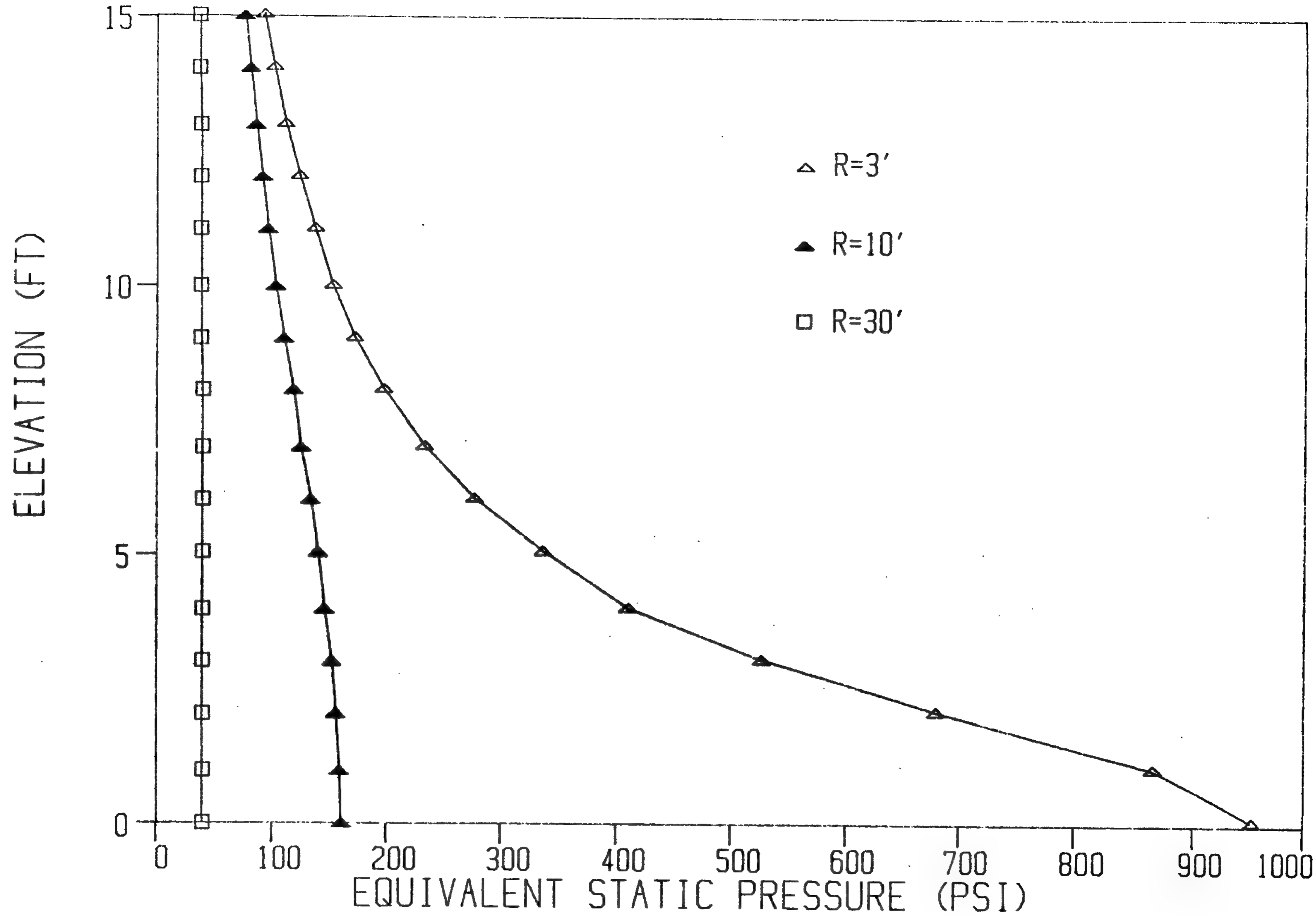


Figure 7. Design loading for 125-pound blast.

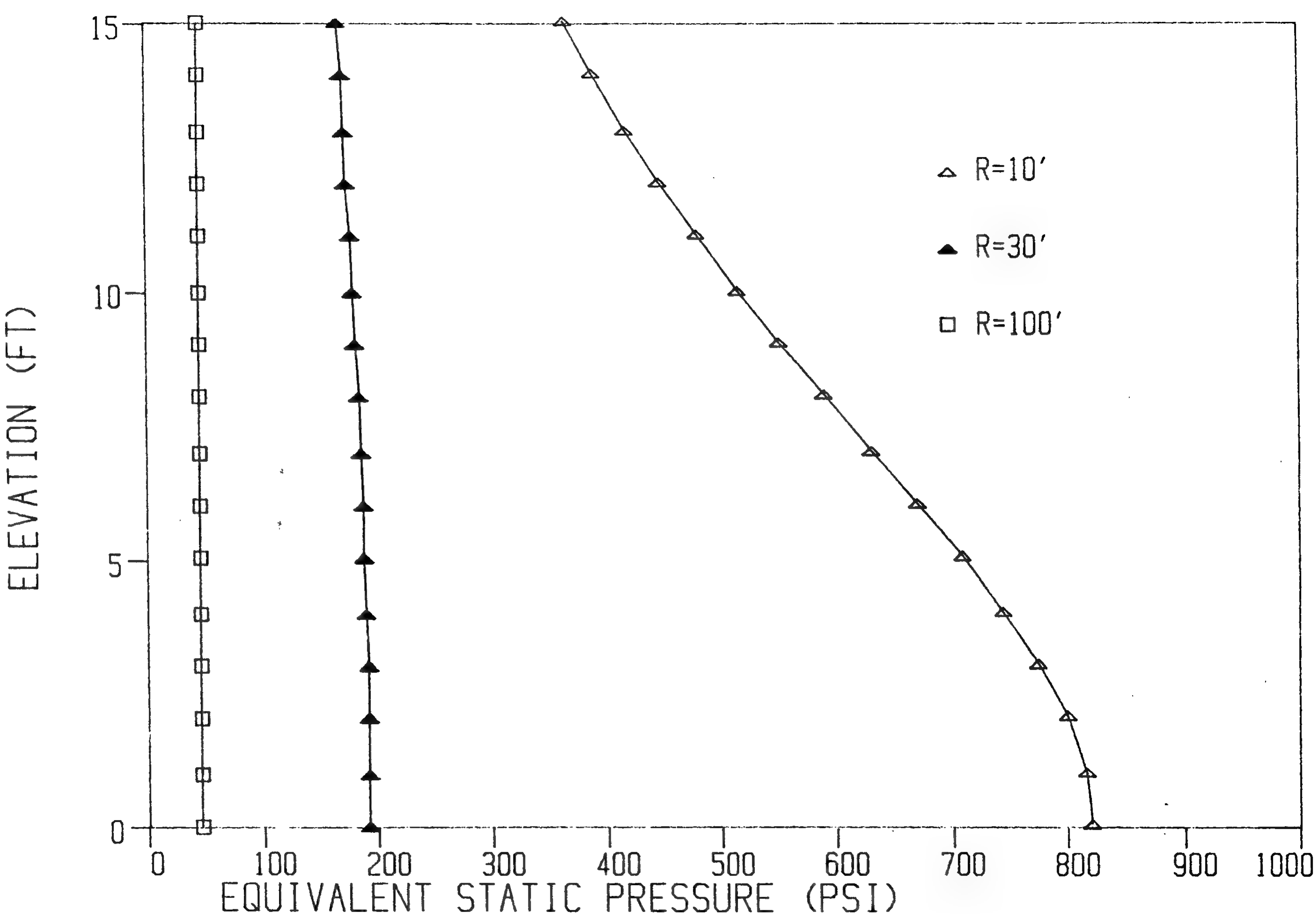


Figure 8. Design loading for 1000-pound blast.

# THE BLAST BARRIER
## -- A BLAST PROTECTION SYSTEM FOR BUILDING AND PERIMETER SECURITY --

By


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### INTRODUCTION

Following the tragedy at the Marine compound in Lebanon, the M. S. Caspe Co. established an intensive research and development effort to protect buildings from the ravages of terrorism. Having developed an Earthquake Barrier system to mitigate loss of both life and property from catastrophic earthquakes, it was a natural first step to see if the Earthquake Barrier system would protect against blast loading without modification. It didn't!

However, with a concerted R&D effort an adaption of the Earthquake Barrier system has resulted in two unique Blast Barrier systems, one for a perimeter wall system that is flexible enough to withstand the direct impact of an exploding truck bomb and the other for a building system to withstand the blast pressure wave that emits from an explosion at whatever distance the perimeter wall is from the building. Both systems utilize friction to dissipate the energy of a blast.

### CURRENT TECHNOLOGY

Currently the design of buildings for protection against blast loading is based on the heavy reinforcement of exterior concrete walls that are cast integrally with the heavily reinforced floors and columns. Windows and doors are both thick and small, in order to resist blast pressures, and structural frames must be strengthened significantly.

This approach is costly to construct -- especially so in third world countries where sophisticated iron workers, carpenters and controlled concreting techniques are not available. It can result in the walls, windows or doors failing locally under blast loading; thereby emitting deadly shrapnel into the building. Should the wall be badly damaged, it is also possible for an attacking force to breach the building and take hostages.

Architects have likened the appearance of designs that meet current blast-resistant criteria to bunkers, which they think unseemly for buildings that represent a free society. Architect's also object to having fixed criteria for design, that do not permit flexibility to adjust to varying site conditions.


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TELEX 278301 RCA UR

The current design of perimeter blast walls utilizes monolithic cast-in-place reinforced concrete that is both strong and rigid. Such walls are not only costly but they are also vulnerable in three respects, namely:

- o If damaged by the blast, the wall could emit deadly shrapnel towards the building;
- o If badly damaged, the wall could be breached by an armed attack; and
- o If too rigid the more flexible truck could collapse and, due to its momentum, roll-over the wall to deliver its deadly fire bomb into the compound.

## THE BLAST BARRIER SYSTEM FOR BUILDING WALLS, WINDOWS AND DOORS

The Blast Barrier building wall system is shown on Figure 1 and is typical of the detail for mounting a Blast Barrier window (within a wall) or a door. To prevent collapse under blast load conditions requires that a wall "roll with the punch" and fall-back, as a boxer does under a blow to the chin. To do this the wall should absorb the energy of the blast by dissipating its kinetic energy under a controlled reaction.

The wall panel (or door) can be designed with conventional building materials, such as precast concrete, masonry block or metal curtain wall. These walls would then be mounted on tracks that are perpendicular to the face of the wall and extend about two feet into the building (as shown on Figure 1). This system is far less costly than monolithic walls and columns because the structural frame need not resist the full blast pressure and because construction is simplified as described below.

The shallow tracks are embedded in the sides of the columns, floors and ceilings in such a way that they are spaced equally about the perimeter in order to serve as brake shoes in the walls or doors under the blast loading. These are formed into the concrete on a reuseable rigid template so that good alignment can be maintained reliably, even though this alignment is not critical. A steel bar is installed in each track to align the wall accurately. These steel bars are coated with stainless steel and hold the full weight of the wall on the teflon sleeves through which they fit. Alignment of the bars is easily done with a screwdriver at the bar alignment collar. This is cost-effective and permits high quality control, particularly where precast wall panels can be cast flat in a precast yard and then lifted into place. While the panel is hung from the crane in a "suitcase lift," the rods can be threaded through the teflon sleeves and then aligned.

Only then are the slide plates prestressed into the tracks -- using a load cell -- thereby compressing the wall against each track location. The amount of prestress force times the coefficient of friction of the slide plate lubricant (such as teflon fabric against stainless steel) predetermines the reaction at which the wall or door begins sliding into the building under the force of a blast-pressure wave. This predetermined reaction is always engineered to be well below the strength of the wall. Hence instead of damaging the wall or door, the blast-pressure wave causes the undamaged wall to accelerate into the building, until the blast pressure has attenuated. Once attenuated, the predetermined reaction serves to decelerate the wall or door until it comes to a stop several inches inside the building.

(1) Department of the Army, The Navy, and the Air Force, 'Structures to Resist the Effects of Accidental Explosions', Technical Manual No. 5-1300, (NAVFAC P-397, AFM 88-22), June 1969.

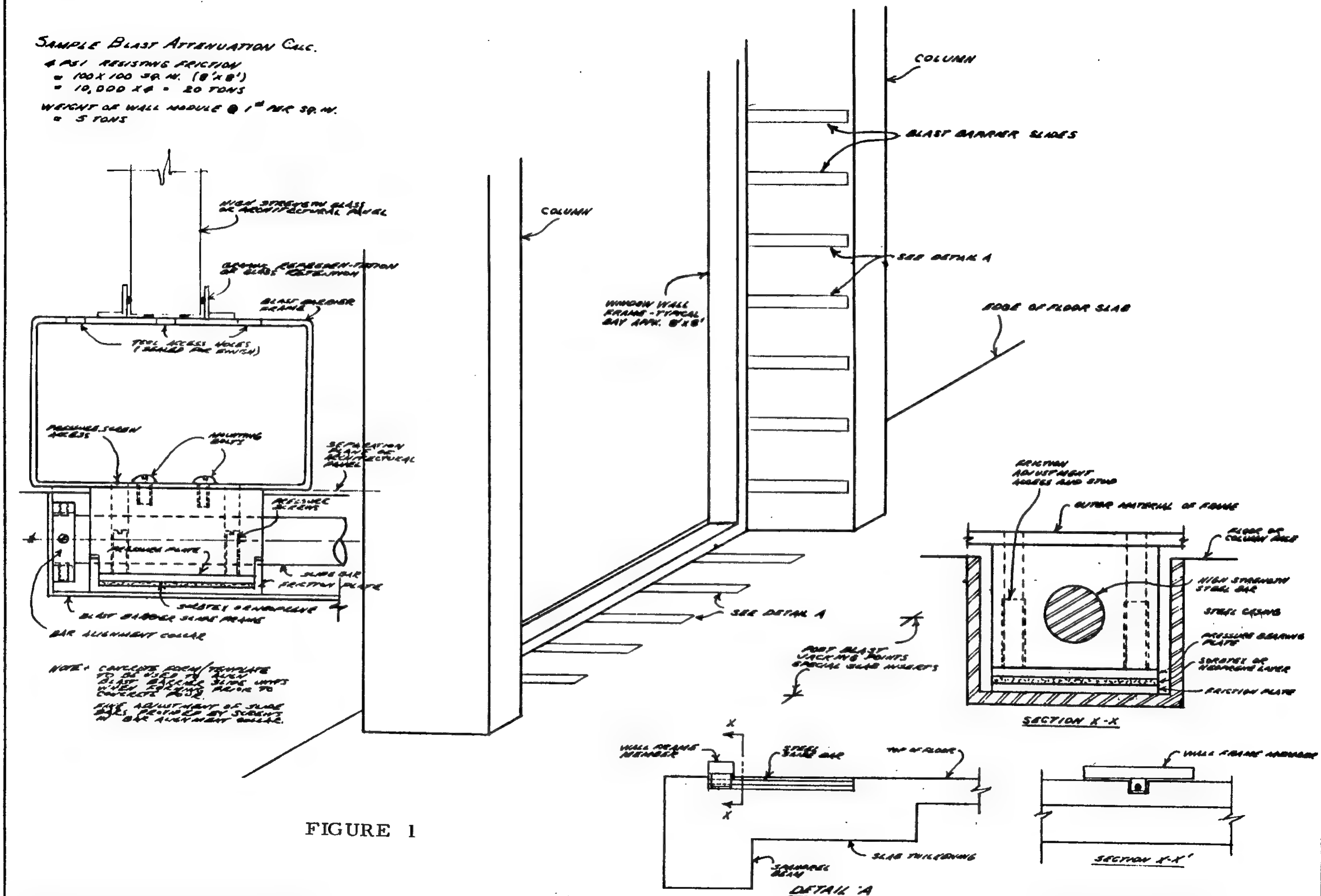



FIGURE 1

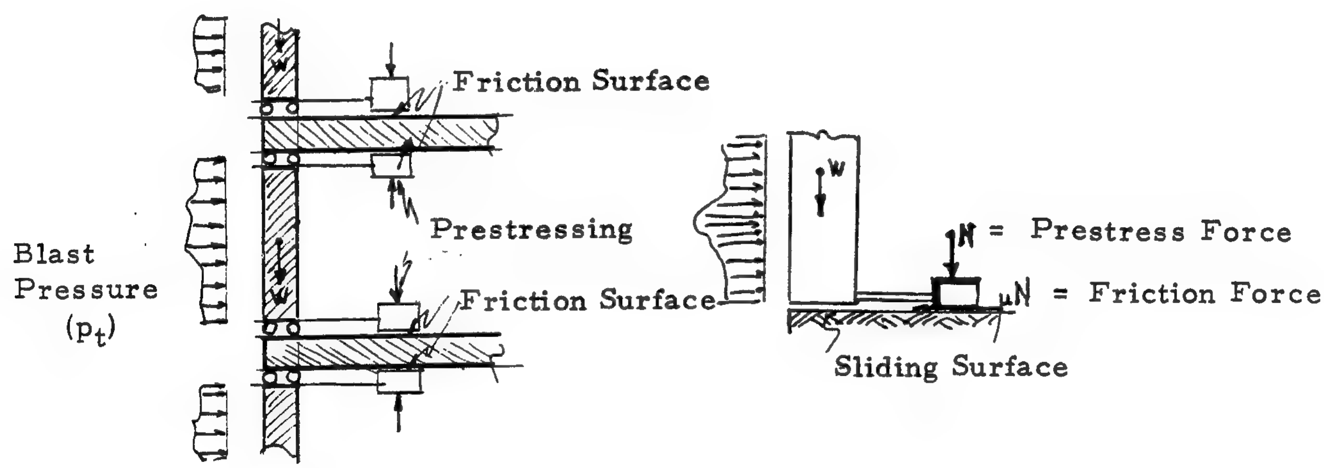
| M.S. CASPE CO., INC. SAN MATEO, CA. 8/21/85 | BLAST BARRIER WINDOW WALL | SCALE ÷ SKETCH U.S. GOV'T BUILDING |
|---|---|---|

Any misalignment of the tracks will have only a minor effect on the Blast Barrier force because of the soft neoprene spring that acts to maintain the pressure relatively constant.

The Blast Barrier design provides a great deal of architectural freedom for using any locally available wall materials such as masonry block. Whatever the strength of the selected wall, window or door, an appropriate Blast Barrier reaction force can be selected. The lower the lateral strength of the material however the further into the building the wall will be required to move. Similarly if a site does not permit a full 100 foot distance between the building and its perimeter walls, accomodations can be made for higher pressures by changing the wall's strength and/or the Blast Barrier reaction force.

Following a blast it is anticipated that the building's walls, windows and doors will not be breached, so that the building can be maintained secure against an armed incursion and secret documents will not be blown out onto the street below. To repair a wall or door after a blast it is only necessary to unbolt the slide plates and jack the undamaged wall or door back into position, prior to again prestressing it into the tracks.

The Blast Barrier system is based on the conversion of the impulse created by the blast into kinetic energy in the wall with a subsequent dissipation of this energy by the friction brake shoes. The mathematical model is illustrated on Figure 2.




(a) Section of Building (b) Detail of Sliding Area

FIGURE 2

THE BLAST BARRIER PERIMETER WALL SYSTEM

The Blast Barrier perimeter wall system is designed to absorb the impact force and energy of a vehicle borne bomb so that the detonation limits the blast pressure that hits the building or troop encampment behind the wall to a tolerable amount, and does so without emitting any shrapnel or permitting the vehicle to roll over the wall into the compound being protected.

Blast Barrier perimeter wall details are shown on Figure 3. The wall is constructed of portable elements that can be manufactured in the United States and exported to overseas building sites or strategic encampments. Installation consists of bolting the 8" wide x 8" high x 32" long steel boxes together with horizontal and vertical bolts that are pretensioned (in a slotted hole that is dry lubricated) to a force level that controls the frictional slippage between adjacent boxes. The amount of prestress times the coefficient of friction of the dry lubricant (such as teflon) predetermines the blast pressure at which the steel boxes are designed to slide against one another. Hence the wall distorts instead of rupturing. This slippage provides both strength and a flexible energy dissipating capability to prevent penetration by the vehicle or roll-over into the compound. If the bolts and washers are properly designed to prevent their rupture or pulling through the slotted holes, no shrapnel should be emitted.

An additional cable through the boxes provides additional reinforcement and energy dissipation. The cable is welded to a metal plate that is in turn embedded in the sand-filled middle chamber. This engages more mass along the length of the wall by pulling the metal plate through the sand. This form of viscous damping is most effective in absorbing both blast and impact loads, particularly within the zone of impact where heavy deformation of the steel boxes could occur.

Because the boxes are small and weigh only 75 pound, they are portable and well-suited for rapidly shipping to troop encampments and airfields in hazardous areas. Where rapid deployment is necessary the fabricated boxes can be stored on pallets at portside facilities, ready for shipment anywhere in the world. When urgency is not required, the boxes can be shipped as plate that is already prepared for full-penetration butt-welding in the field. This will serve to reduce the cubage required for shipping to scheduled construction sites.

The exterior wall of the Blast Barrier could be covered with an architectural veneer to give whatever appearance is desired. The wall inside the compound could also be treated architecturally or it could be a sloped earthen backfill to provide additional energy dissipation as an integral system with the Blast Barrier perimeter wall.

Following a blast it is anticipated that the perimeter wall will not be breached, so that the area behind it can be maintained secure against an armed incursion. To repair the perimeter wall it is only necessary to unbolt the slide plates and re-erect those sand filled steel boxes that have not been badly distorted into a plumb position, replacing those that have been distorted.

The wall will stay stationary under all wind loading but under a blast pressure the friction force will be exceeded. The friction force will be in equilibrium with a minimum Blast Barrier pressure ($p_{bb}$), where:

$$p_{bb} = \mu N / A$$

and "$p_{bb}$" is the pressure to be resisted by the Blast Barrier system, "$\mu$" equals the coefficient of friction, N equals the total in-track prestress force around the wall perimeter and "A" equals the area of wall exposed to the blast. The pressure at which the motion will start sliding can be adjusted to levels compatible with the resistance of the wall by simply adjusting the total in-track prestress force.

The impulse applied by the blast will move the walls with a velocity "v", calculated by the conservation of impulse as:

$$v = (g/W) \cdot \int_{t_o}^{t_d} \int_A p(t)\, dA\, dt$$

wnere "W" is the weight of the wall and "g" equals the gravitational acceleration.

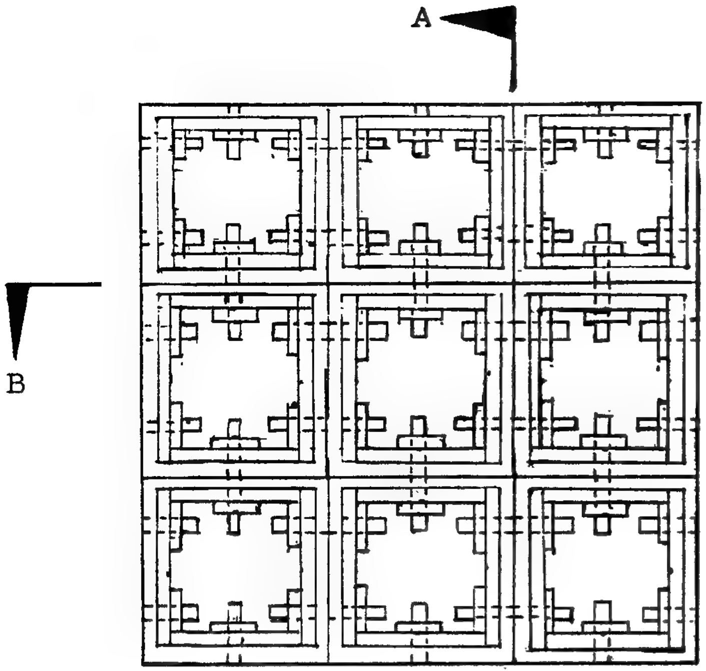
The kinetic energy of the moving wall, $Wv^2/2g$, will be dissipated by the friction force while sliding to a displacement d; where:

$$d = g \cdot \left[ \int_{t_o}^{t_d} \int_A p(t)\, dA\, dt \right]^2 / 2\mu N W$$

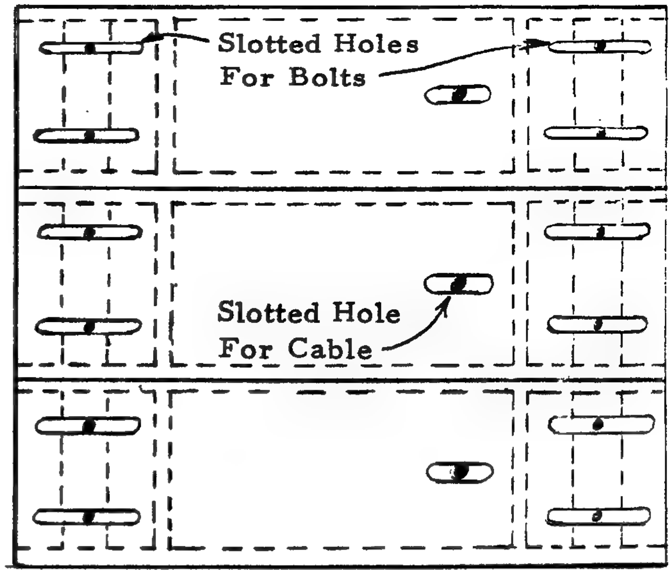
It is obvious that the distance "d" can be controlled by proper design of wall's weight "W", however a similar effect can more readily be obtained by adjusting the in-track prestressing force "N" and/or the friction coefficient "$\mu$" to establish the Blast Barrier force.

Figure 2 shows the blast pressure ($p_t$) to have an irregular magnitude that varies across the wall. The frequency content of the blast pressure will induce curvature and distortion into the wall in many modes of vibration other than the fundamental mode, (although the fundamental mode will be the principal cause of a damaging wall blowout). Since the Blast Barrier system provides protection principally against the fundamental mode of vibration -- wherein the wall bowes into the building in a single smooth curve -- a safety factor (and a little reinforcement) must be provided to protect against the localized spalling of concrete under higher modes of vibration. The safety factor needed for final design, to prevent localized spalling and the issuance of any concrete shrapnel into the building, requires a detailed diffraction analysis and ultimately a series of blast tunnel tests.

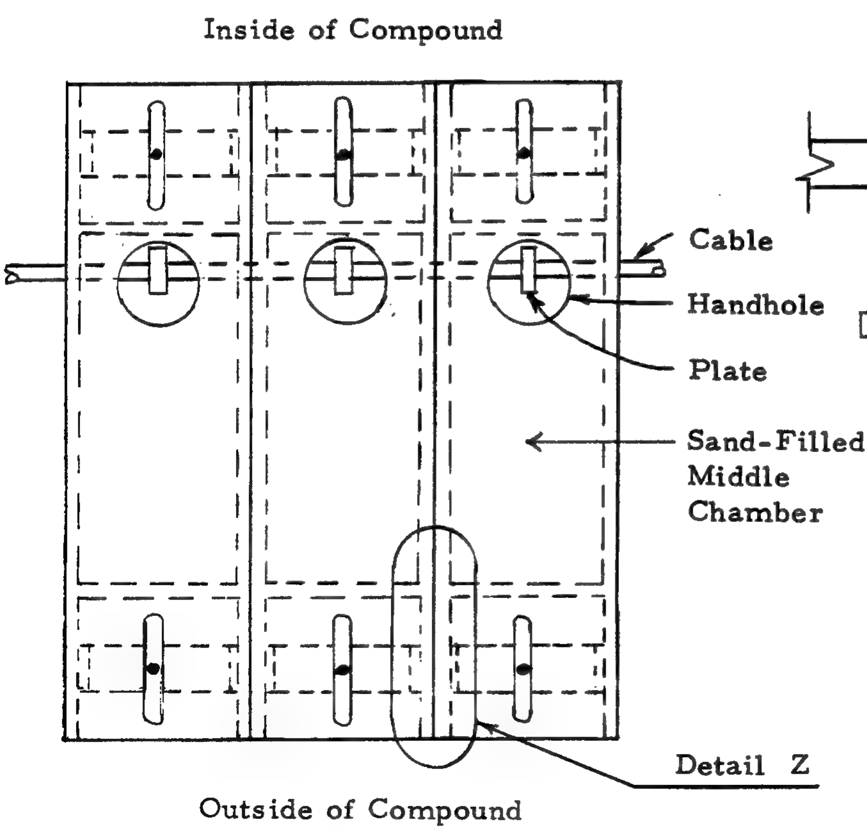
The Blast Barrier building wall system has been described above as it applies to new construction. Currently efforts are being made to develop retrofitting details by adding a new facade to an existing building. This facade could be set as little as 5 feet or as much as 20 feet from the existing exterior wall, thereby adding usable floor space to the building.



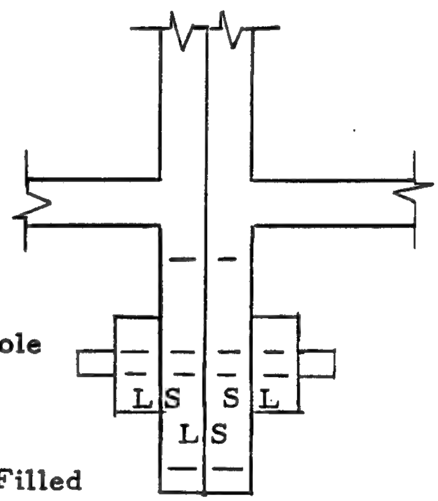

PERIMETER WALL ELEVATION




SECTIONAL ELEVATION A




SECTIONAL PLAN B




DETAIL Z

"S" indicates a stainless steel coated surface

"L" indicates a dry-lubricant coated surface

FIGURE 3

BLAST BARRIER
PERIMETER WALL
DETAIL

## DISCUSSION AND CONCLUSIONS

Both Blast Barrier systems utilize the principle of energy dissipation, such as the frictional drag of a brake shoe, to establish a reaction threshold level that avoids damage to building elements from the fundamental mode of a blast pressure wave. By setting the threshold reaction at a value that is well below the strength of the building's walls, windows and doors, these elements will move into the building without damage. The elements will stop their motion due to friction drag forces between the moving surfaces, thereby dissipating the energy of the blast. The safety factor chosen as the difference between each element's ultimate strength and the Blast Barrier reaction force is utilized to safely withstand any localized high stress conditions that might be induced by the sharp curvature of higher mode vibrations. Benefits that can be cited for the Blast Barrier system include:

- The system will provide enhanced safety for personnel by reducing the potential for shrapnel to burst into the building;
- The system has design flexibilities that permit simple adjustment of the friction force reaction levels;
- The system uses a combination of shop fabricated parts (much of which can be manufactured stateside and exported) and local materials that can keep the costs low and the quality of workmanship high (even in remote areas of the world):
- The system enhances architectural design freedom;
- The sytem inhibits penetration by an armed force (because the walls are not breached) and prevents security papers from blowing out of the building;
- The system can easily be "repaired" after a blast so that it is returned to its original location, appearance and level of safety; and
- Finally, the system has a potential for use in retrofitting existing facilities, both structurally on an entire building and non-structurally on interior filing cabinets and computers.

CRR

Crisis Readiness and Response

Crisis Readiness and Response (CRR) is designed to support our commercial customers. Created from the wide range of professional services provided to our government clients, CRR is comprehensive and tailored to meet corporate needs in a cost-effective manner. Our staff, distinguished by its expertise and rich experience, welcomes the opportunity to serve you.

JAYCOR

# CRR
## Crisis Readiness and Response

### What is Crisis Readiness and Response?

One important management responsiblity is ensuring its company is prepared for precipitious events such as terrorist and criminal assaults, extortions, and intrusions.

The goal is to take appropriate actions before a crisis so as to minimize a loss or even turn the event to the company's advantage. Properly prepared senior management is then able to respond to a crisis aggressively, quickly, and confidently.

Recently, the corporate leadership of a major multinational firm was concerned about the threat to their planned headquarters building in New York.

What was the threat from terrorist and criminal elements?

What would protection cost – how should they get the most for their money?

Was it feasible to harden the building structurally?

Should operational procedures be emphasized?

What role should technical sensors play?

Could the necessary security be accomplished without designing a fortress?

What about training for security personnel? For all personnel?

They came to JAYCOR for help.

### What is JAYCOR?

JAYCOR is more than a consulting firm!

We assist clients not only in concept development, but in the translation of the concept into action to include:

* selecting, acquiring, and installing technical systems;
* providing necessary training;
* staging exercises and evaluating performance.

The company's staff of over 500 provides a wide range of professional, technical, and scientific services from 16 offices throughout the United States.

JAYCOR uses this broad spectrum of experts in an interdisciplinary approach to create coherent, comprehensive action plans. If necessary, we can also tap numerous sources for specialized expertise or unique information. Our success is based on the ability to identify and implement cost effective and result oriented solutions.

**How can JAYCOR prepare my company for crisis?**

JAYCOR's emphasis on integrated, realistic solutions requires careful definition of your problem.

Our experts sit down with your management, staff, and technicians to identify clearly all aspects of the problem and, most importantly, to determine constraints on the solutions.

With the problem defined, JAYCOR considers recommendations suggested by its experts in each field. These unconnected recommendations are analyzed by JAYCOR consultant integrators who choose and blend only those ideas necessary to create a logical, integrated action plan which responds to your problem.

After review and approval by your company, JAYCOR's experts can help translate their respective parts of the plan into effective company action. With implementation, your company is ready to move quickly to end the crisis and return to a normal mode of operations.

— — — — — — — — — — — — — —

For the New York multinational described earlier, JAYCOR surveyed public and private information to identify the terrorist groups which posed the most likely threat and to determine their methods of operation including size of bombs used.

JAYCOR engineers, applying an extensive knowledge of weapon and bomb effects, worked directly with the client's structural engineers. Potential damage to key structural elements was calculated and alternatives for hardening the building were designed to ensure structural integrity.

The structural hardening was just one aspect of an overall counter-strategy. Operational procedures were designed, technical sensor systems were chosen, and personnel recruitment and training objectives were determined.

The end result was an integrated security plan which opposes the current threat and is dynamic enough to detect and adjust for changes in the threat.

Detailed descriptions of the following Crisis Readiness and Response services are contained in this folder:

* **Threat Analysis and Definition**
* **Structural Hardening for Planned and Existing Structures**
* **Security Operations and Procedures**
* **Personnel Selection and Training**
* **Crisis Management Training**
* **Secure and Robust Communications Network Design**

These services can be used individually, or as shown in the example above, they can be synergistically combined when appropriate.

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# THREAT ANALYSIS AND DEFINITION

A critical first step to integrated security management is a thorough understanding of threats posed by those who want to disrupt your company's operation. Threats may originate from terrorists intent on creating chaos or injury, from criminal elements preparing extortions or kidnappings, from competitors operating unethically, or from disgruntled ex-employees seeking revenge for perceived wrongs.

Overestimating the threat results in wasteful expenditure of your resources. Under-estimation is a double curse: it leaves you vulnerable while giving you a false sense of security.

Threat analysis and definition forms the basis for an achievable counter-strategy:

* the size and content of a potential bomb affects your decisions on structutal hardening;
* the methodologies and sophistication of the threat influence the composition, training, and operating procedures of your security force;
* contingency plans and exercises should be tailored to the specific threats.

JAYCOR responds to your company's unique needs. We meet with your staff and management to establish protection priorities. We assess your corporate image and determine any attendent attractiveness to terrorist and criminal groups. We survey the environment of affected sites to determine the social, economic, and political factors which impact the threat definition process.

For example, the improvement of physical security at U.S. embassies abroad tends to increase the proclivity of terrorist groups to strike more vulnerable American commercial facilities.

Based on analysis of the information gathered, JAYCOR experts assess the dynamic interplay of all factors relevant to the threat. The result is a detailed threat definition that delineates the current threat and projects that threat into the future by examining trends.

The quality of JAYCOR's threat assessment is based on the quality of our staff which has broad experience in domestic and foreign intelligence and law enforcement. We are tied into one of the world's foremost information hubs - Washington, D.C. We know where the best information is available and our networks keep us appraised of both short term developments as well as long-term trends.

With the threats defined, JAYCOR specialists are available to help you in producing a coherent and affordable counter-strategy which responds effectively. Our Crisis Readiness and Response staff is expert in translating these recommendations into detailed action including hardening of structures, devising of integrated security operations (both equipment and personnel), creation and exercising of contingency plans, and design of resilent communications systems.

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# STRUCTURAL HARDENING AND REDESIGN

A building resistant to terrorist activity or civil unrest does not have to look like a castle! Many proven techniques are available to harden structures against bomb, weapon, and other threats without interfering with the flow of corporate operations.

JAYCOR has accumulated a wealth of experience in this arena, supporting building programs which span the globe. Our engineers analyze the effects of bombs and projectiles against a wide variety of structures, both existing and planned. For instance, the dynamic loading caused by a bomb exploding near a structural element can be translated into equivalent static loads familiar to building structural engineers.

We work directly with your structural engineers and architects to identify the key structural elements of your building which could be exposed to a potential threat. Together, we can develop and assess alternative building design and architectural options.

Incorporating hardening into a building project at the design phase is obviously easier and less costly. However, JAYCOR can also apply innovative and cost conscious techniques to an existing facility.

Structural Hardening and Redesign is most effective when used in conjunction with other JAYCOR Crisis Readiness Services. Threat Definition and Analysis plays a key role in bounding the threat, often resulting in a more modest, realistic, and achievable response. In effect, we are able to define the threat against which the architects and structural engineers must design.

Structural Hardening and Redesign is a critical element of an integrated threat response, combining with Operations and Procedures, Personnel Selection and Training, Secure and Robust Communications, and Crisis Management Planning to afford you the optimum strategy for reducing risk to corporate operations.

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## SECURITY OPERATIONS AND PROCEDURES

Individuals who seek to disrupt, compromise, or endanger corporate operations are a priority security concern. The objective is to unmask the guilty, inside the company or outside, here or abroad, and stop them before harm is done.

Security Operations and Procedures are effective when they are current and there is an underlying clear understanding of the specific requirements. JAYCOR experts provide you the necessary analysis to balance cost versus benefit. The result is a discriminating definition of what you must protect: critical operations, inventories, people, information, equipment, and facilities. JAYCOR will then assist you with implementing an appropriate concept of operations and related procedures.

All your employees are charged with security responsibilities, albeit to a varying degree. Security Operations and Procedures, therefore, must be prepared and tailored to reach each audience. Above all, security instructions must be understandable and current. They must promote efficient, fluid, and effective responses.

JAYCOR is able to assemble a multi-disiplinary team to meet your security needs. Present on our staff are former FBI, CIA, Secret Service, Defense, and State Department officers. Each contributes unique insights into the threat posed to your company's operations and in the development of a comprehensive security program.

Guided by an appreciation of escalating costs for the recruitment and training of qualified people and the acquisition and installation of technical systems, JAYCOR builds a strategy for you from which security procedures are written. Our product is marked by its ability to anticipate crisis, promote flexible and phased responses, creativeness, and deterrent value.

One important part of your security counterstrategy is the installation of cameras, sensors, and other technical equipment. JAYCOR experts have designed and installed such systems at facilities around the world. These cost-effective layouts were successful because they used an integrated approach tailored to the specific needs of each site.

Security Operations and Procedures is only one facet of an integrated approach to defeating the threat. An important first step is definition and analysis of the threat so that valid responses are used. Other parts of a complete counter-strategy include hardening facilities structurally, selecting and training personnel, designing hardy communication systems, and creating and testing tailored crisis management procedures.

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# PERSONNEL SELECTION, TRAINING, AND EVALUATION

People are the vital asset in any organization yet pose the most serious risk. Disruption in a company's operation is caused most often by people who should not be occupying the position because the selection process failed, inadequate training was provided, or a meaningful evaluation of performance was not conducted on a regular basis.

JAYCOR can assist you in developing and implementing a personnel recruitment and selection program. We will help you define the operational requirements and specify the types of individuals needed in terms of experience, education and training, and integrity. JAYCOR will aid in verifying information gathered and submitted.

The design of a professional training program is preceded by a clear understanding of the requirements and an appreciation of the range of people involved. Senior managers in all companies are trapped between the unavailability of time and their wide range of additional responsibilities for which some training is required.

JAYCOR, sensitive to these constraints, designs interesting, innovative exercises and training sessions that meet these demands. For example, one and a half day session for operational specialists was reconfigured into a two hour and a half hour "table top" exercise tailored for senior management's crisis management responsibilities. The success of the exercise was measured by the enthusiastic and full participation of these managers whose only complaint at the end of a comprehensive day addressing the terrorist threat was, "We wish the session had been <u>longer!</u>"

JAYCOR also understands the more detailed requirements for those charged with readiness and response on a daily basis. For example, a security force was given practical bomb threat training which included exercises in searching for practice bombs. The training and exercises were geared to the level of experience and education of the client's guard force. Again its success was based on our understanding of the specific environment and operational requirements. The end result was a more confident and professional security force.

Finally, no selection and training program will satisfy emerging contingencies if an objective evaluation program is not instituted. JAYCOR's independent evaluation process can periodically assure that you are able to meet any conceivable threat with the resources at your disposal.

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## CRISIS MANAGEMENT PLANNING

In fast-breaking situations, such as bomb threats, kidnappings, fire emergencies, civil unrest, or power, computer or communications failures, management must have at its fingertips a plan of action which anticipates the situation, is current, and is accompanied by procedures with which selected staff are familiar.

JAYCOR can help you prepare for a wide variety of crises. We have accumulated vast experience in identifying the real requirement, and in formulating workable plans and procedures to meet them. Our experts complete the necessary research and visit selected sites before they begin to tailor the results to meet your company's needs.

We recognize that it is impossibe to predict the exact nature of every crisis or its timing. However, by building a concept of phased implementation and flexibility into each plan, we increase your readiness to meet an escalating or evolving threat.

Effective crisis management also requires careful planning and allocation of supporting resources. A kidnapping of one of your executives abroad would require assembling previously selected senior executives; centralized work space and pre-identified and prepared information; reliable communications; and the ability to draw upon the full range of internal corporate assets plus outside resources to resolve the crisis.

We understand the wide diversity of responsibilities and expertise of those involved in crisis operations. For example, procedures written for key decision makers are not as detailed as those written for staff members with their respective sectors of operational responsibility. Our plans and procedures are self-explanatory because senior decision makers frequently do not have the time to review them prior to a crisis.

Your confidence in your company's ability to function in an emergency rests on the currency, relevancy, and thoroughness of your plans and procedures. To the extent possible, we integrate crisis-oriented preparation into your day to day operation. We believe that this approach is most sensible, the least costly, and promotes a smooth transition into crisis operations.

Crisis Management Planning is best accomplished in concert with other JAYCOR Crisis Readiness and Response services which define the threat and then design efficient communications and security systems which respond to that threat.

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# SECURE AND ROBUST COMMUNICATIONS

Most modern corporations are increasingly dependent upon the efficient transmission of information through voice, data, fascimile, and video links. Properly designed communications systems will provide this service while:

* preventing access to unauthorized users
* ensuring error-free message receipt
* maintaining high priority flow in degraded communications environments

JAYCOR has extensive experience in the design, acquisition, and installation of communications systems which meet these criteria. For instance, we helped a client plan a secure worldwide network using existing commercial carriers. We have also designed networks for customers who owned transmission systems to include satellite, microwave, high frequency radio, meteor burst, and coaxial and optic cable capabilities.

After the conceptual design stage, JAYCOR can advise you on selection of specific communications components which satisfy your requirements. Objectivity is assured: we neither represent equipment manufacturers nor are we manufacturers ourselves. After purchase, our technicians are available to install and test the components both in the U.S. and abroad, offering you in the process a "turnkey" system.

JAYCOR has also assisted clients in the recruitment and training of communications system personnel. We can provide a wide range of assistance for your maintenance and logistics functions. Supported by an experienced graphics and publications staff, we produce high quality technical manuals for systems operations, maintenance, and training needs.

The communications network is supported by other Crisis Readiness and Response services. The security threat is examined at each location and an integrated response devised using structural hardening and appropriate operational procedures.

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CORPS OF ENGINEERS
ANTITERRORISM AND PHYSICAL SECURITY
RESEARCH PROGRAM

by

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and
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U.S. ARMY CONSTRUCTION ENGINEERING RESEARCH LABORATORY
Champaign, IL

Paper Presented at
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## Abstract

In 1984 the U.S. Army Construction Engineering Research Laboratory (USA-CERL) was tasked by the Office of the Chief of Engineers Directorate for Research and Development to be the Executive Agent for the Antiterrrorism and Physical Security Research Program of the Corps laboratories. These laboratories are the U.S. Army Engineer Waterways Experiment Station, the U.S. Army Cold Regions Research Engineering Laboratory, the U.S. Army Engineering Topographic Laboratory and USA-CERL. The Corps laboratories, as part of their overall mission, are to plan, execute, evaluate and disseminate research results for the purpose of improving the physical security aspects of the planning, design, construction, operation, maintenance and repair of military and civil works facilities.

Currently within the Corps laboratories there are three on-going work units related to antiterrorism and physical security research and development. These work units impact the military construction, and operation and maintenance phases of the facility life cycle at differenct stages, ranging from facility planning to maintenance and repair. In addition, a reimbursable program nearly twice the size of the sustaining program is directed towards performing physical secuity research in support of other federal agencies.

In summary, the Corps laboratories have extensive experience and capabilities in antitierrorism and physical security research and development, can develop Army-wide criteria rapidly, have capabilities that go beyond the Department of Defense, and have a program coordinated with the technical centers of expertise which supports the Vice Chief of Staff tasking.

## Introduction

The Corps of Engineers Antiterrorism and Physical Security Research Program was formally established in late 1984 to insure an integrated effort among the Corps laboratories. These laboratories are the U.S. Army Engineer Waterways Experiment Station (USAE-WES), the U.S. Army Cold Regions Research Laboratory (USA-CRREL), the U.S. Army Engineering Topographic Laboratory (USA-ETL) and the U.S. Army Construction Engineering Research Laboratory (USA-CERL). This paper presents an overview of the Corps of Engineers Research Program in support of the Army's need to provide security for its personnel and property. The paper covers the problem, and background to the problem; the Corps' mission within the Army and its responsibilities; the current research, development, testing and evaluation program; and the capabilities within the Corps community.

Over the past 16 years, incidents of international terrorism have steadily increased. Since 1968 there have been at least 9720 terrorist incidents reported world wide according to the U.S. Army Intelligence and Threat Analysis Center. Approximately 35% or 3375 of these incidents have occurred in the last 5 years. The value of losses associated with threats from terrorism to theft, and the cost of providing security to protect against these threats is extremely high. Losses have been estimated to be about $94 M annually to the Navy alone and the cost of Department of Defense (DOD) security guards exceeds $1.8 B annually. Security upgrade programs within the Army exceed $1 B.

The U.S. Army's concern over terrorism has risen over the last decade because of the increase in the number of threats against U.S. military facilities and personnel world-wide. Terrorist incidents involving just the U.S. and the DOD have been increasing. Many of the terrorist incidents involving U.S. military and DOD personnel and property are violent and destructive. Examples of Anti-DOD incidents include the Frankfurt Military Shopping Center bombing, Beruit Barracks bombing, the bombing of Muniz Airfield Puerto Rico, the shooting of a military officer in San Juan Puerto Rico, the car bombing of the Rhein-Main Air Base, the San Salvador Cafe massacre and the kidnapping of General Dozier. From a low of 68 incidents in 1968 to a high of 386 incidents that strictly involve U.S. military or DoD personnel or property terrorism has risen dramatically.

While the majority of terrorist incidents against the U.S. military have occurred in Europe and the Middle East locations in the U.S. have also been subject to terrorist attacks. Examples are the bombings at Ft. McNair, Washington Navy Yard, the Capitol and Army and Navy reserve centers. Other sites centered in the Washington, D.C. area have also been identified as potential targets by terrorists.

## Army's Response

Within the DOD community the Department of the Army's (DA) mission in physical security is in providing expertise for physical security equipment

(PSE). This includes among other equipment components barriers, lighting and interior Intrusion Detection Systems (IDS). In response to the antiterrorism/physical security problem and within their mission area the Army has:

a. Managed the research and development for the Army's component of physical security equipment through a single office, Project Manager Physical Security Equipment.

b. Established an Antiterrorist Task Force for the purpose of determining how the Army may best combat the terrorist threat and where improvements are needed in order to accomplish this.

c. Conducted a Functional Area Assessment of the physical security needs and funding requirements at the major commands.

d. Tasked the Corps with researching, developing and designing protective measures for military personnel and property.

e. Established a Crisis Response Cell to counter a terrorist attack.

## Corps' Responsibilities

The Corps' mission in physical security is defined in AR 190-11, "Physical Security of Arms, Ammunition, and Explosives;" AR 190-12, "Military Working Dogs;" and AR 190-13, "The Army Physical Security Program." Specifically the Corps' role in physical security is defined in The Army Physical Security Program, AR 190-13, 1-5(h). The Chief of Engineers is responsible for:

a. Ensuring physical security criteria are considered in the design characteristics of new or modified military construction and are coordinated with the responsible physical security office.

b. Developing procedures and techniques to install and maintain all IDS for Army installations and activities.

c. Programming and budgeting funds for the maintenance and repair of Government-owned PSE at facilities and installations, and for the installation of Government-owned PSE.

d. Ensuring proper design, installation and maintenance of DOD and DA standardized and commercial IDS projects by means of the establishment of an IDS Technical Center of Expertise.

e. Identifying costs associated with procurement and installation of PSE as part of military constrcution projects.

f. Meeting construction responsibilities and identifying problem areas that impact on physical security design.

In order to improve the protection of Army personnel and property the Corps has designated technical centers of expertise for antiterrorism/physical security design. Huntsville Division is the Technical Center for Intrusion Detection Systems and the center of technical expertise for protective design is located at the Missouri River Division. The Corps of Engineers Directorate for Research and Development has also established an Executive Agent for coordination of the research and development at the Corps laboratories and tasked the labs with specific research areas. USA-CERL is Executive Agent for Physical Security Research and the Lead in System Integration Research. USAE-WES is the Lead in Component Performance Research, i.e., sensor performance, barrier and facilities hardening. USA-CRREL is the Lead for Research in the Effects of Snow, Ice, and Frozen Ground on Physical Security Systems. USA-ETL will support the Corps as required. The technical centers and research tasking afford the Corps a coordinated effort in physical security research, development and design.

## Current Program

Within the Corps there are currently three funded RDT&E programs. The objective of the Integration of Physical Security into Construction is to develop guidance for facility planners and designers for the cost effective integration of physical security into new and existing facilities. This program will be discussed in more detail later in this paper. The program, Analytical Techniques for the Design and Application of Sensors, will soon be completed. Seismic, acoustic and electromagnetic signatures of military and terrorist intruders and the theoretical aspects of signature propagation were investigated to support the development of environmentally insensitive security sensor configurations for detecting, classifying and/or locating targets. The development of design guidelines to increase the survivability of military facilities subjected specifically to the terrorist attack is the objective of Protection from Terrorist Attack. Mr. David Coltharp, USAE-WES, will discuss this program in more detail in another paper.

As the Corps laboratory for total systems integration research USA-CERL is responsible for developing a holistically integrated process for incorporating multi-technology alternatives into a fixed facility. The ongoing physical security program at USA-CERL is aimed at integrating physical security construction requirements with functional requirements at the lowest life cycle cost. This integration process includes retrofitting existing facilities and the design of new construction. The research includes: threat definition, criteria for site planning and facility layout, a basis for physical security component selection, criteria for rating one design over another, and related research critical to the assessment of total system performance.

USA-CERL is developing a methodology which will allow the base commander to determine the required level of security to be provided a new facility and to assess the existing physical security at his installation. The planner/designer will be able to rationally choose among security alternatives for new facilities and improvements to existing facilities in order to provide this required level of security.

Inconsistencies in DOD physical security, especially the variation in the levels and costs of security were noted in a Government Accounting Office report. This document identifies the need for guidance to be provided to the facility planner and designer, and the base commander and security officer in their development of an overall physical security posture.

An initial step in determining the level of security necessary for any facility or installation is to determine the design threat. The USA-CERL program for the Corps of Engineers is concerned with the full range of threats, from terrorist attacks to theft. Threats may be grouped into high, medium and low categories based on their severity. The facility function also plays an important role in determining the level of security to be provided. Facility categories are established with respect to their criticality in the performance of a mission. A cost effective security design is related to the threat and the function of a facility/installation. In a simplified analysis this relationship may be expressed in matrix form and represents the required level of security for a faciltiy. Where the criticality of a facility function is high and/or the threat severity is high a value of 7, 8, or 9 may be assigned from the matrix. This justifies a greater level of required security, perhaps the use of hardened construction, an intrusion detection system and/or extensive guard patrols. Conversely a value of 2 or 3 implies low criticality and severity and a facility in this range may simply require improving the security of vulnerable elements of the structure. Such improvements may include the addition of door locks and bars on the windows. An understanding of the design threat for a facility or installation is essential in the development of a methodology for the cost effective integration of physical security into construction. The final security design must reflect a realistic assumption of the required level of security.

USA-CERL is also investigating currently available methodologies for incorporation into military construction physical security concepts. The Physical Security Requirements Assessment Methodology developed by the Naval Civil Engineering Laboratory, Port Hueneme is being tested at Ft. Ord, CA and evaluated for the Army's use. Other products of the research program are a Preliminary Physical Security Selection and Evaluation Procedure available for testing in 1987, a Site Planning and Facility Configuration Design Guide available for use in late 1986, and a final Physical Security Selection and Evaluation Procedure which will include the design guide principles and a risk assessment model. This methodology will be available for use in 1990.

In addition to the Corps sponsored research ongoing at the laboratories physical security research work is being funded by a variety of agencies on a reimbursable basis. Since 1981 USA-CERL has provided the Defense Nuclear Agency (DNA) with expertise in the development of new concepts for weapons storage facilities and has researched the use of foam denial systems to defeat the terrorist threat for these facilities. USAE-WES has developed analytical criteria for buried line sensors for the Air Force and performed data aquisition and analysis for multiple sensor processing for DNA. USAE-WES has also performed testing in the development of advanced storage concepts and security management concepts for DNA. They are supporting the State

Department in their effort to improve the posture of their facilities against blast loading. Tempest shielding systems have been developed at USA-CERL for the Albuquerque District of the Corps of Engineers.

In summary the experience and capabilities of the research laboratories and the technical centers of expertise can be seen by the products they have produced and their ability to respond to the needs of the Corps. The technical expertise available addresses a wide range of areas and the capability of the Corps to integrate this knowledge allows the development of innovative solutions to problems. In addition to solving some of the physical security problems of the Army, the Corps is also able to assist the wider arena of the DOD and other Federal agencies, NATO and other allies. The Corps has developed a coordinated program which complements its expertise and serves its mission.

# RESEARCH ON PROTECTION OF BUILDINGS FROM CAR-BOMB ATTACK

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## ABSTRACT

The design of buildings for protection from the effects of car bombs is discussed. Many of the applicable design procedures are well-established and have been developed for structures to resist the effects of accidental explosions and conventional weapons. However, there are certain design problems associated with the car-bomb situation for which reliable procedures are not available and for which research is being conducted or planned. These areas include the effects of close-in detonations on masonry walls, the design of perimeter walls and their effects on reducing blast loads from a vehicle bomb, the design of windows, and the design of sacrificial panels for reducing wall loads. Tests to verify existing procedures are also discussed.

# CORPS OF ENGINEERS - CONSTRUCTION PROGRAM REVIEW

by
Larry Sand, P.E.
Omaha District Corps of Engineers

## ABSTRACT

The Omaha District Technical Center of Expertise (TCX) was formed to develop and maintain Corps of Engineers physical security design criteria in addition to coordinating protective design efforts. One of the first tasks of the TCX was to review the Army's current construction program. To accomplish this task, the TCX developed a method to evaluate the vulnerability of each project to various terrorist threats, including the moving and the parked car bomb. Analysis of the results of this review revealed several important conclusions, which are summarized at the end of this report.

INTRODUCTION:

The Corps of Engineers designs and constructs billions of dollars worth of facilities yearly for the Army, Air Force, and many other clients. In the past, security aspects of a facility or installation were often secondary considerations, being incorporated as an afterthought or by renovations after construction. With the advent of the terrorist threat in the last few years, there has been a growing concern over the susceptibility of Corps constructed facilities to terrorist incidents.

The Corps currently has several different component agencies working on terrorist-related activities. These include the following:

1. Waterways Experiment Station (WES):

    a. Blast and weapons effects on various wall types and structural systems.

    b. IDS research and development.

2. Construction Engineering Research Labs (CERL):

    a. Research on the integration of security into facility construction.

    b. Physical security evaluation procedures.

3. Cold Regions Research and Engineering Laboratories (CRREL): Environmental effects on IDS sensor performance.

4. Huntsville Division: Intrusion Detection System-Technical Center of Expertise (TCX).

5. Missouri River Division/Omaha District: Protective Design-Technical Center of Expertise (TCX).

The following report describes the Omaha District TCX and its related work in a physical security review of the current Corps of Engineers construction program. This review examined Army-wide Corps projects under construction or being designed for their vulnerabilities to six different terrorist threats, including those of moving and parked car bombs.

HISTORY:

As a result of the rapid increase in terrorist activity since the mid-70's, the Corps of Engineers has become increasingly aware of the need to design security measures into their buildings and facilities.

In order to coordinate this effort, the Corps established the Omaha District as the Protective Design Technical Center of Expertise (TCX).

MISSION:

As the Protective Design Technical Center of Expertise, the Omaha District has the following mission:

Maintain a state-of-the-art technical expertise for protective design and coordinate Corps of Engineers activities in this field. The protective design field includes the following subjects: nuclear weapons effects-resistant design, conventional blast-resistant design, nuclear-biological-chemical (NBC) protection, electromagnetic pulse (EMP) protection, physical security design, anti-terrorism design, ammunition facility design, and intrusion detection systems (IDS).

Assist Headquarters, United States Army Corps of Engineers in program guidance, technology transfer, and coordination with other agencies. The Center of Expertise will provide technical design service and advisory assistance to Corps of Engineers Districts and Divisions upon request.

FUNCTION:

In performing its mission, the Omaha District will be capable of performing the following special functions:

a. Review and assist in investigations and in feasibility studies and project reports.

b. Review and assist with economic analyses, cost estimates, design memoranda, and design analyses.

c. Assist other agencies as required.

d. Monitor technological advancements and recommend research relative to equipment, processes, materials, and design procedures. Maintain liaison with industry and appropriate research laboratories. Undergo continuous training to maintain a staff qualified to prepare in-house designs or review designs of others.

e. Serve as a point-of-contact for protective design expertise.

f. Recommend designs, theories, and construction approaches for both specific projects and for standardized design. Recommend any testing required to validate design formulas and materials.

g. Participate in technical meetings and conferences to develop outside contacts and to keep abreast of emerging technology.

h. Assist in updating, revising, editing, or developing design criteria related to protective design.

REVIEW OF CONTRUCTION PROGRAM:

One of the first tasks received by the TCX was to review the Army's current construction program to identify projects which need additional physical security measures to protect them from potential terrorist activities. This task within itself was monumental as the construction program contains more than 2000 projects.

In order to accomplish this task, the TCX developed a Review Criteria which could be utilized by all Corps of Engineers Divisions and Districts along with the various Major Commands (MACOMs) within the U.S. Army to review their projects. In overview, the philosophy of the Review Criteria was to use a simplified numeric approach which included both objective and subjective values. MACOMs were required to provide input into the subjective values in order to improve the validity of the results. This simplified method, although not ideal, was determined to be the best method to accomplish the stated purpose in the time frame allotted.

With this philosophy in mind, the first step in developing the criteria was to define the types of terrorist attacks or scenarios which might be perpetrated against an Army facility or installation. A total of six different scenarios were identified which encompass the majority of known terrorist attacks against facilities. These include: 1) Moving Car/Truck Bomb, 2) Parked Car/Truck Bomb, 3) Covert Sabotage, 4) Unauthorized Entry, 5) Stand-off Attack, and 6) Exterior Bombing. Although there are several additional terrorist threats (e.g., kidnapping, assassination, hijacking, etc.), it was felt that the six identified are the threats in which the engineering community can most effectively address. Additionally, anything done to alleviate the six stated threats may reduce the vulnerability to the unspecified miscellaneous threats.

Once the threats were defined, all projects were placed through a detailed analysis to determine their need for additional physical security protection. This detailed analysis included determining a rating in three different categories: Attractiveness, Vulnerability, and Concern/Consequences.

The overall Attractiveness rating was threat-dependent and was based equally upon three different factors: Mission Criticality, Dollar Value, and Personnel Density.

The second category evaluated was that of Vulnerability. A given project's vulnerability varies with the threat posed against it. Accordingly, six different flow diagrams were developed to assess a project's vulnerability against a given threat. These flow diagrams take into account both those actions necessary for a terrorist to accomplish his goal and also the physical security means which will prevent or inhibit him from accomplishing his goal. The flow diagrams for both the moving and the parked car bomb are included as Figures 1 and 2. In addition, the construction matrices necessary to use these flow diagrams are included as Figures 3 and 4. These flow diagrams are utilized by answering site specific questions and accumulating

points. After completing these diagrams, the total number of points is used to select a Vulnerability rating. By going through each flow diagram, the physical security inadequacies become apparent and, in turn, lend themselves to design solutions. It is in this category that engineers will be able to make the largest impact in reducing a project's susceptibility to terrorist attack.

The third category to be evaluated was that of concern/consequences. This rating was determined by the Major Command for which the project is being constructed. This rating is subjective in nature and takes into account such things as the symbolic nature of the target, the psychological impact, the media impact, and the history of terrorist activity in the geographical location of the project. This category is also threat dependent.

Once the values for a project's attractiveness, vulnerability and concern/consequences were determined for each of the six attack scenarios, an average for the three values was calculated. These six average values are an indication as to how vulnerable and susceptible a given project might be to each type of terrorist attack and are referred to as risk indicators. These risk indicators were used to determine which projects, if any, may need corrective actions.

Each Corps Division Commander had the responsibility to make the final determination as to what was to be done with each project. His decision was based upon the analysis of the project's attractiveness and vulnerability to terrorist attack and the command's concern/consequences. Appropriate actions will be initiated based upon his recommendations.

RESULTS OF REVIEW:

Several interesting developments occurred during the process of compiling the results of this review. Some of these are discussed below:

1. Several of the facilities reviewed required immediate corrective actions to correct vulnerabilities. The majority of these projects were highly personnel intensive. These include administration and headquarters buildings and academic facilities.

2. Review of the construction program indicated that nearly one-fourth of the projects had vulnerabilities, but could be modified to correct these at a later date when resources are available. The deficiencies noted were not significant enough to modify or delay these projects at the present time.

3. The remaining projects were deemed acceptable from a protective design perspective and changes were not necessary.

4. Corrective actions to mitigate the car bomb threat included the following:

a. Installation of berms and landscaping features to act as passive protective features.

b. Siting of parking areas to increase standoff distance.

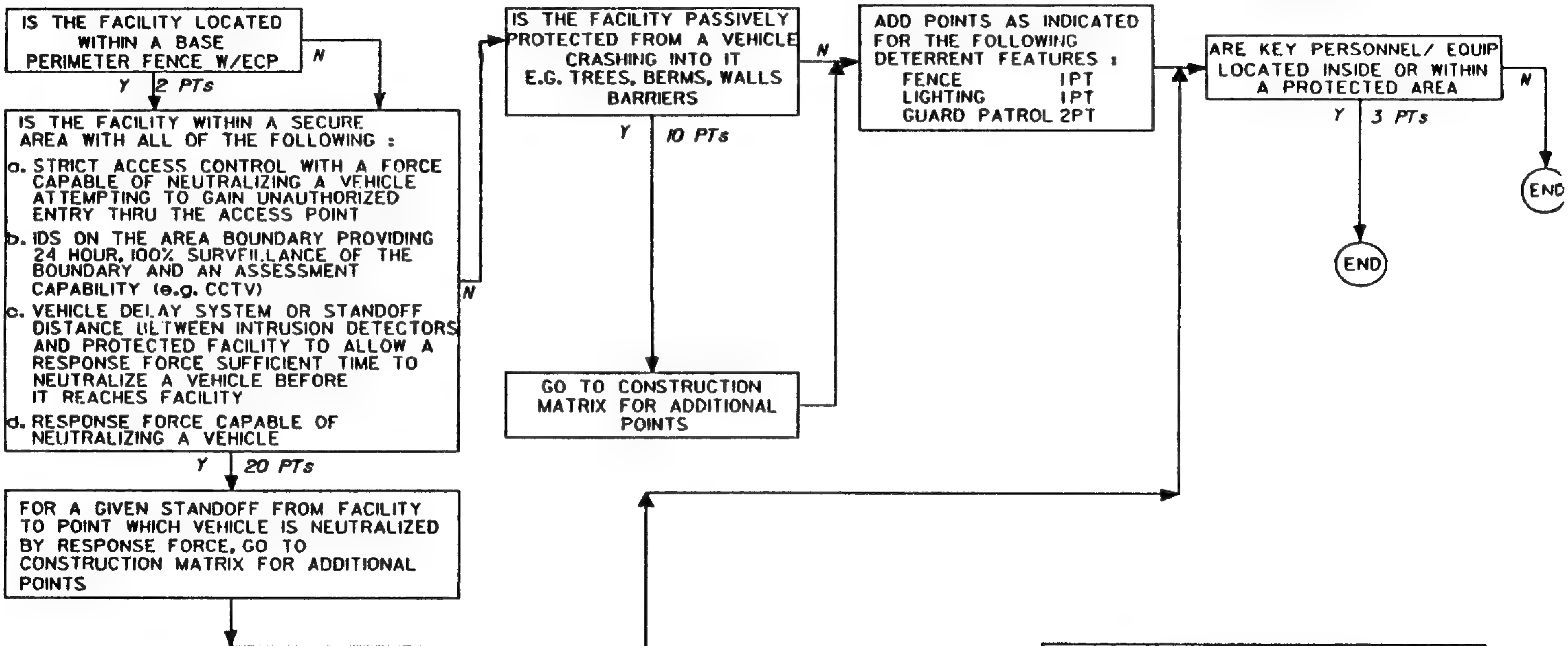
c. Increased access restrictions to the immediate vicinity of the facility.

d. Change in type of building construction to mitigate blast damage.

5. This review produced a worthwhile side benefit in that it raised the level of awareness among engineers and planners for anti-terrorist design considerations. The significance of this benefit cannot be overemphasized since the Corps and MACOM personnel who participated in the review have a signficant influence on installation planning and facility design. Sensitizing these key personnel will help ensure that anti-terrrorist measures are incorporated into future installation and facility designs.

**FIGURE 1**

# VULNERABILITY FLOW DIAGRAM
# THREAT # 1 - MOVING CAR / TRUCK BOMB




| POINT RANGE CHART | |
|---|---|
| TOTAL POINTS | VALUE |
| 25 TO 30 | 1 |
| 21 TO 24 | 2 |
| 17 TO 20 | 3 |
| 9 TO 16 | 4 |
| 0 TO 8 | 5 |

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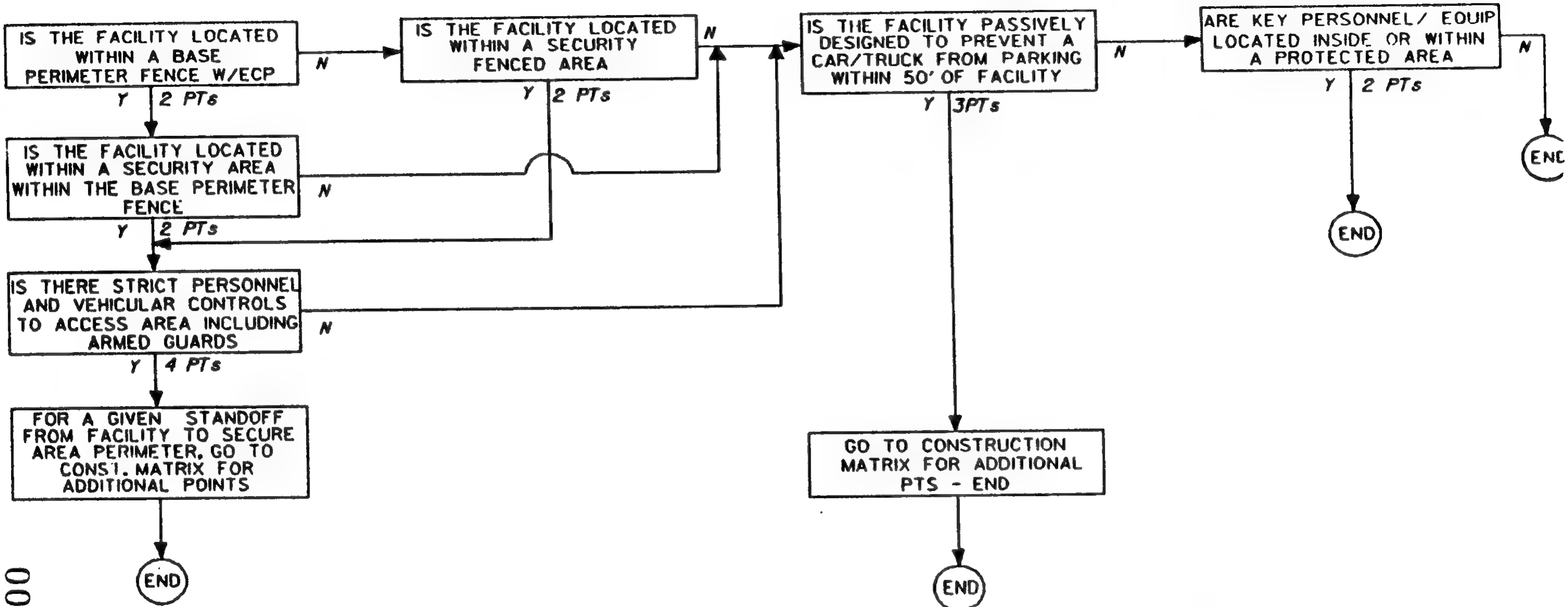
**FIGURE 2**

# VULNERABILITY FLOW DIAGRAM
## THREAT # 2 - PARKED CAR / TRUCK BOMB




| POINT RANGE CHART | |
|---|---|
| TOTAL POINTS | VALUE |
| 11 TO 13 | 1 |
| 9 TO 10 | 2 |
| 7 TO 8 | 3 |
| 5 TO 6 | 4 |
| 0 TO 4 | 5 |

| Stand-off Distance / Type of Construction | >700' | 500'to700' | 300'to500' | 50'to300' | <50' |
|---|---|---|---|---|---|
| Sheet Metal; Wood; Lath & Plaster | 1 | 0 | 0 | 0 | 0 |
| Brick; Unreinforced Masonry (Single Wythe Const) | 2 | 1 | 0 | 0 | 0 |
| Double Wythe Unreinforced Brick or Masonry or Combo Single Wythe Reinforced Masonry; 8" Nominal Reinf Conc. | 3 | 2 | 1 | 0 | 0 |
| 8" Conc w/#4@9" EW EF; Reinforced Double Wythe Const; 12" "Substantial" Conc. Wall (#4@12 EW-EF) | 4 | 3 | 2 | 1 | 0 |
| Concrete - Blast Designed Heavily Reinf (p=0.005) >12" Thick | 5 | 4 | 3 | 2 | 1 |

FIGURE 3 - Vulnerability Construction Matrix Threat #1 - Moving Car/Truck Bomb

| Stand-off Distance / Type of Construction | >700' | 500' to 700' | 300' to 500' | 50' to 300' | <50' |
|---|---|---|---|---|---|
| Sheet Metal; Wood; Lath & Plaster | 1 | 0 | 0 | 0 | 0 |
| Brick; Unreinforced Masonry (Single Wythe Const) | 2 | 1 | 0 | 0 | 0 |
| Double Wythe Unreinforced Brick or Masonry or Combo Single Wythe Reinforced Masonry; 8" Nominal Reinf Conc. | 3 | 2 | 1 | 0 | 0 |
| 8" Conc w/#4@9" EW EF; Reinforced Double Wythe Const; 12" "Substantial" Conc. Wall (#4@12 EW EF) | 4 | 3 | 2 | 1 | 0 |
| Concrete - Blast Designed Heavily Reinf (p=0.005) >12" Thick | 5 | 4 | 3 | 2 | 1 |

FIGURE 4 - Vulnerability Construciton Matrix Threat #2 - Parked Car/Truck Bomb

# LOW COST MODULAR COLLECTIVE PROTECTION USING THE IMPROVED PROTECTIVE ENTRANCE/TENT (IPE/T) SYSTEM

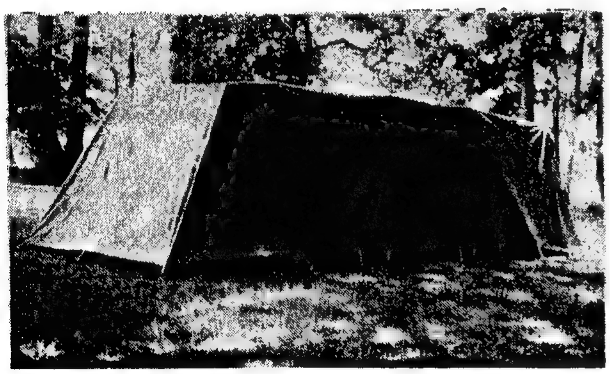
by

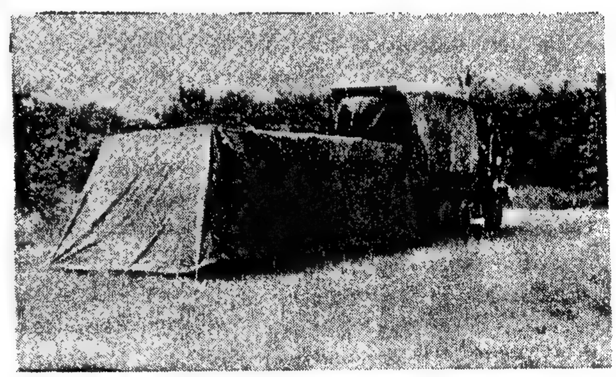
George D. Summers, Ph.D.[1]

March, 1986

## Introduction

Developed and demonstrated under TEC's IR&D, U.S. Army and USAF contracts[2], the basic IPE/T system provides positive internal pressure and filtered air for personnel in a chemical warfare environment. The basic design includes donning/doffing area, decontamination area and toilet area which adjoin large work/rest areas. The modular feature of the IPE/T (see Figures 1 and 2) permits it to be interfaced with tactical ground or vehicle-mounted shelters, van-semitrailers, buildings or other IPE/T units and use internally in large buildings and structures. Figure 3 shows the floor plan of an IPE/T connected to an S-280 signal shelter.





The NBC filtered exhaust air from the shelter or facility filtration system provides the required IPE/T pressure and airflow. In the stand-alone configuration, an electric or diesel driven FBU supplies the filtered air. Many possible interface and deployment configurations for the IPE/T system are made possible by the use of the inherent modular (building block) design approach.

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717-235-3867

[2]Contract Nos. DAAK11-83-C-0078, DLA900-85-C-0395, DAAJ01-84-D-0005

## Deployment

The IPE/T is ideally suited for deployment in a multitude of operations. It is light weight (130 lbs) and its cube (two duffle bags) makes it easy to transport. Two men can deploy an IPE/T module in less than 15 minutes. Each IPE/T then provides a purging airlock (protective entry), a toilet area and a large work/rest area (collective protection) for up to twelve persons. Positive pressure for each IPE/T is provided by a 100 cfm supply of filtered air which maintains the main compartment pressure at over 0.5 iwg. Some of the various deployment configurations are shown in Figures 4, 5 and 6. (Note that the IPE/T can even be used in conjunction with existing buildings.) Contamination control and collective protection is enhanced by the IPE/T as it provides a clean area for many missions including: Rest & Relief, Medical, Command and Control, Weapon, Maintenance, Security, Air Defense, Logistics and General Purpose.

## Developmental Testing

During the development of the IPE/T, pressure and flow rate tests were performed to design the control orifices into and out of each of the areas within the IPE/T. The decon area receives purging air from two sides thus inducing a circular flow before the air passes out through orifices in the outer access door.

Recent design refinements include: the use of a reflective metallic coating (Reflectec) to minimize heat gain, the option of adding camouflage for all exterior surfaces and a frame system capable of withstanding a 10 lb/sq. ft. snow load.

Initial field trials conducted at CRDC, Edgewood, MD in June 1984 demonstrated functional deployment of the IPE/T system with a truck-mounted S-280 shelter. A similar event in April 1985 demonstrated the deployment with an S-250 shelter. The multiple interface module (used to connect many basic IPE/T systems into a larger complex) was field tested in May 1985.

Infiltration testing was successfully completed at CRDC in September, 1984 and November 1985. In these tests, sulfur hexafluoride ($SF_6$) was introduced into a 20 mph wind which flowed over the IPE/T. The tests were conducted with and without the protective fly and with the wind striking the IPE/T from several different directions. The IPE/T withstood steady state winds of 30 mph and gusts above 40 mph (during startup and checkout of the aircraft engine used to generate the winds). A highly successful full scale live agent test was conducted in December 1985.

Extended field trials are presently being conducted around the United States.

## Summary

The IPE/T collective protection system has proceded from initial demonstration to advanced testing and field trials in less than two years. Reports from the field indicate that it is rugged, easy to deploy and effective. Continued refinements to the design have resulted in a low cost collective protection system which is ready for full scale production. The low cost helps to make it the most versatile and cost effective system available today.

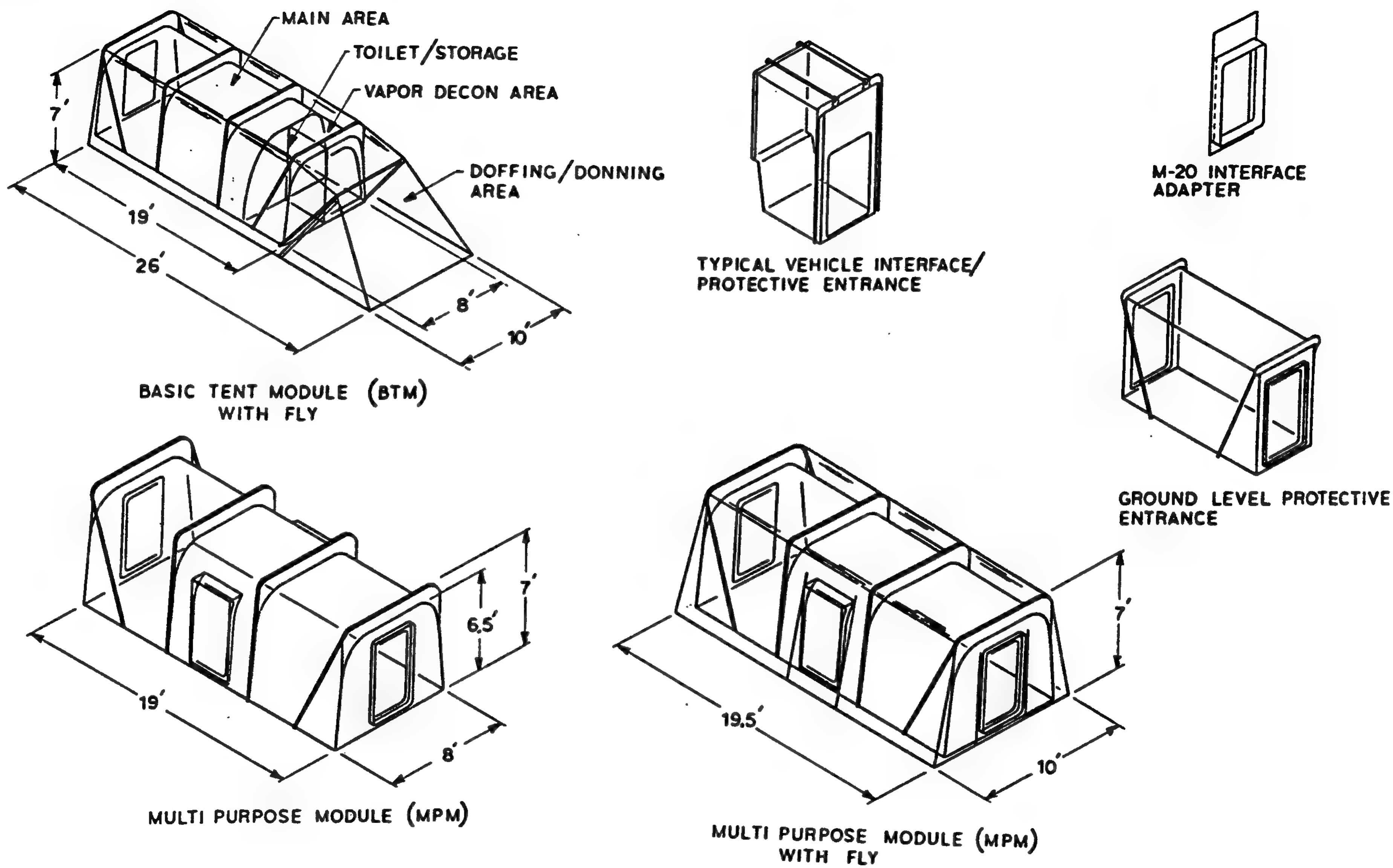


Figure 1. IPE/T MODULAR SYSTEM COMPONENTS

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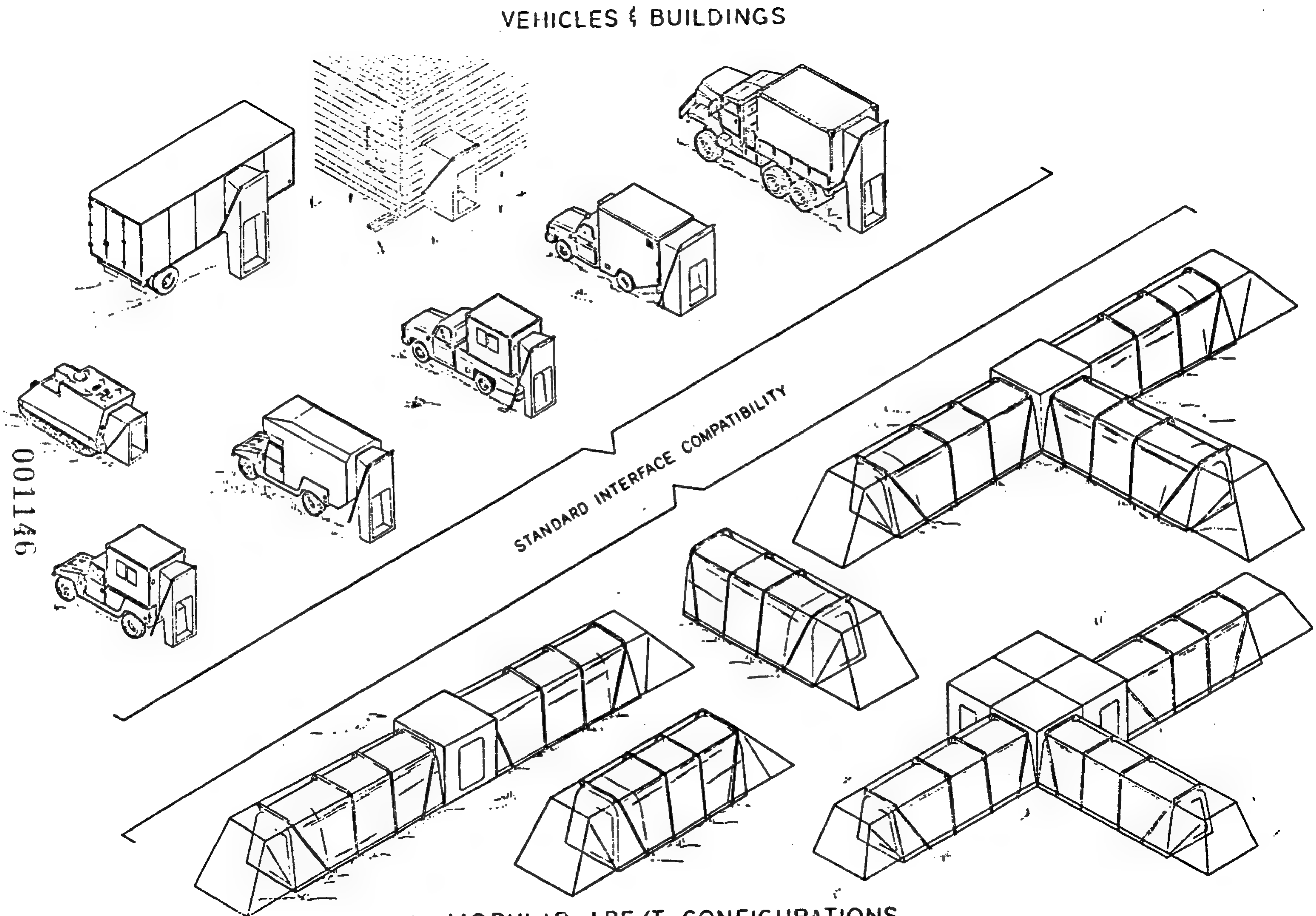


Figure 2. MODULAR IPE/T CONFIGURATIONS FOR INTERGRATED AND STAND-ALONE OPERATIONS

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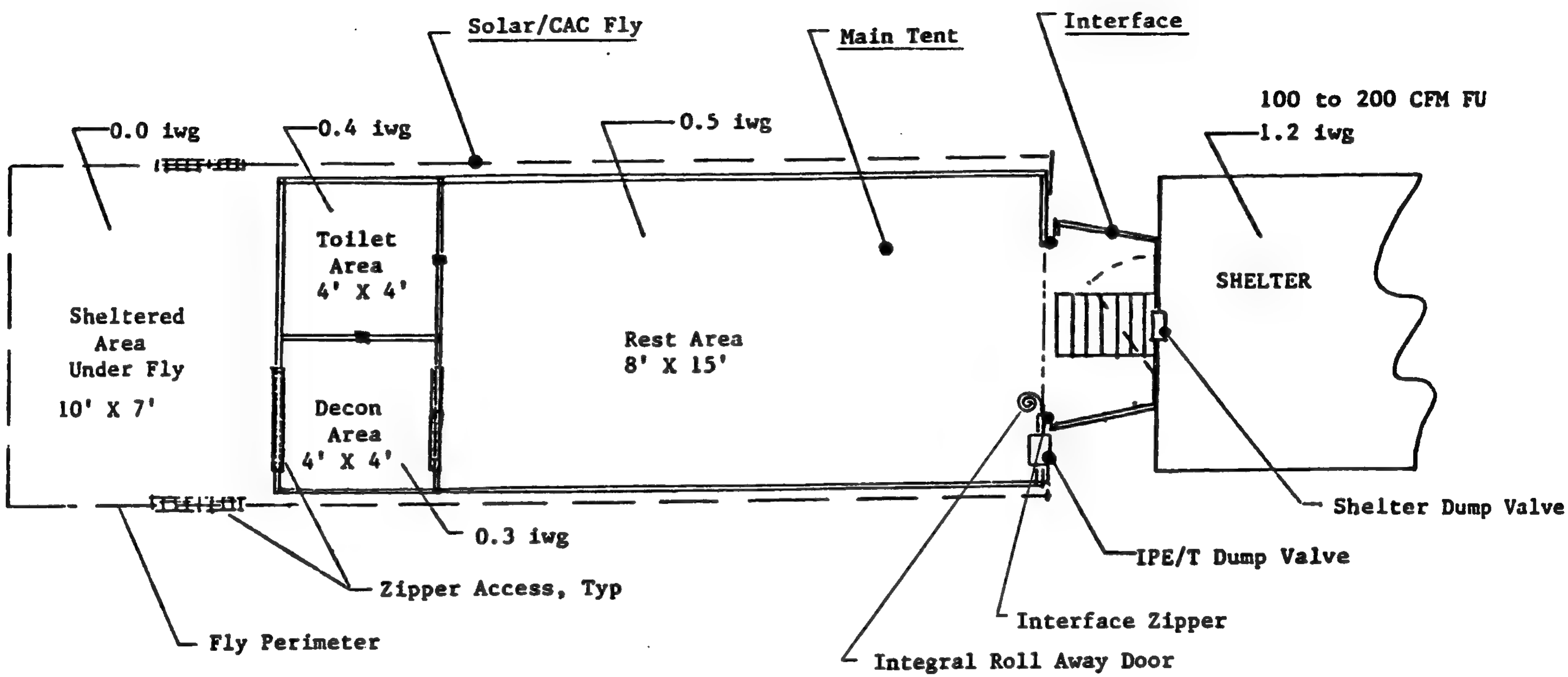


Figure 3. PLAN VIEW OF IPE/T, FLY AND SHELTER INTERFACE

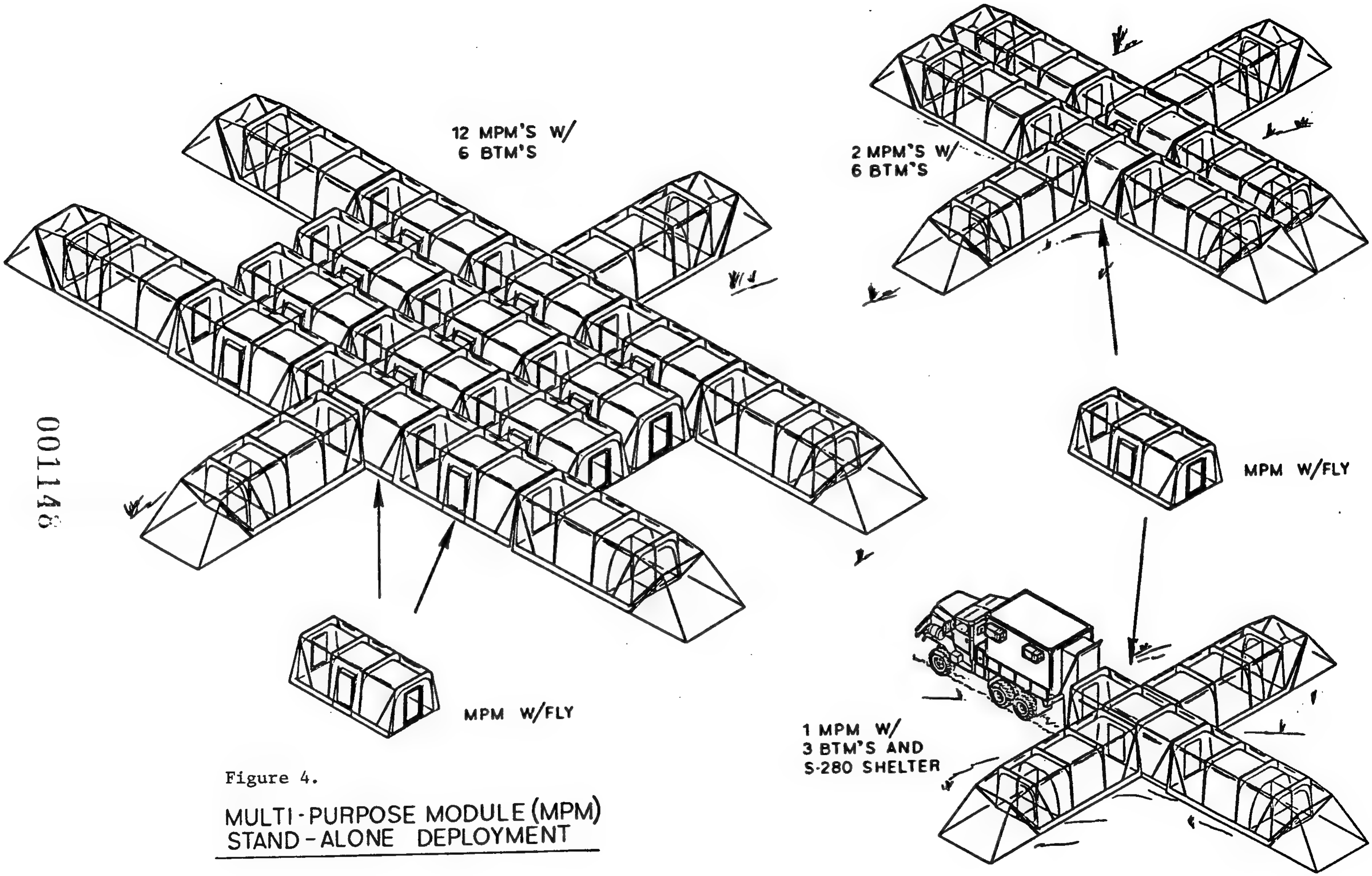


Figure 4.

MULTI-PURPOSE MODULE (MPM)
STAND-ALONE DEPLOYMENT

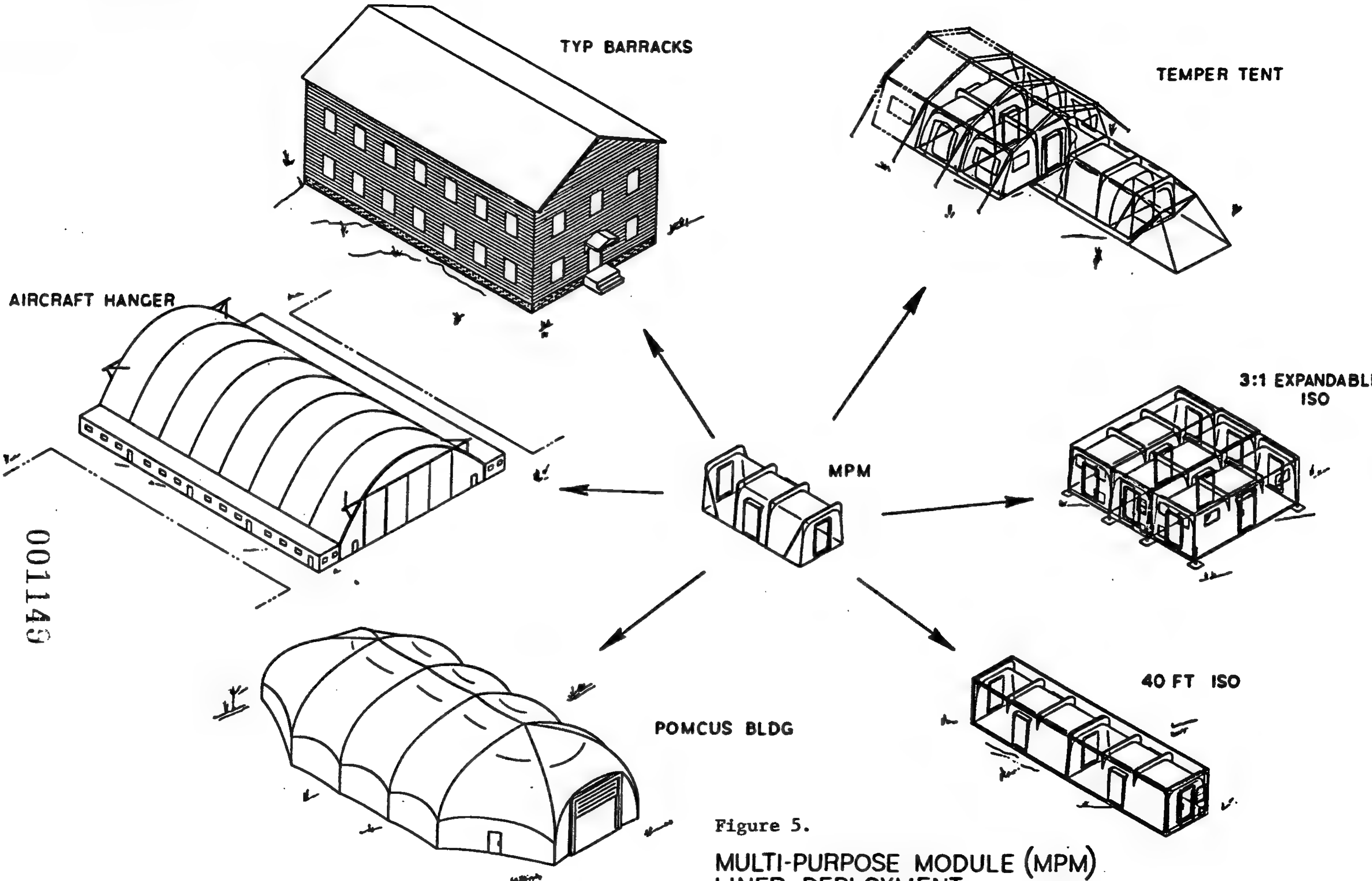


Figure 5.

MULTI-PURPOSE MODULE (MPM) LINER DEPLOYMENT

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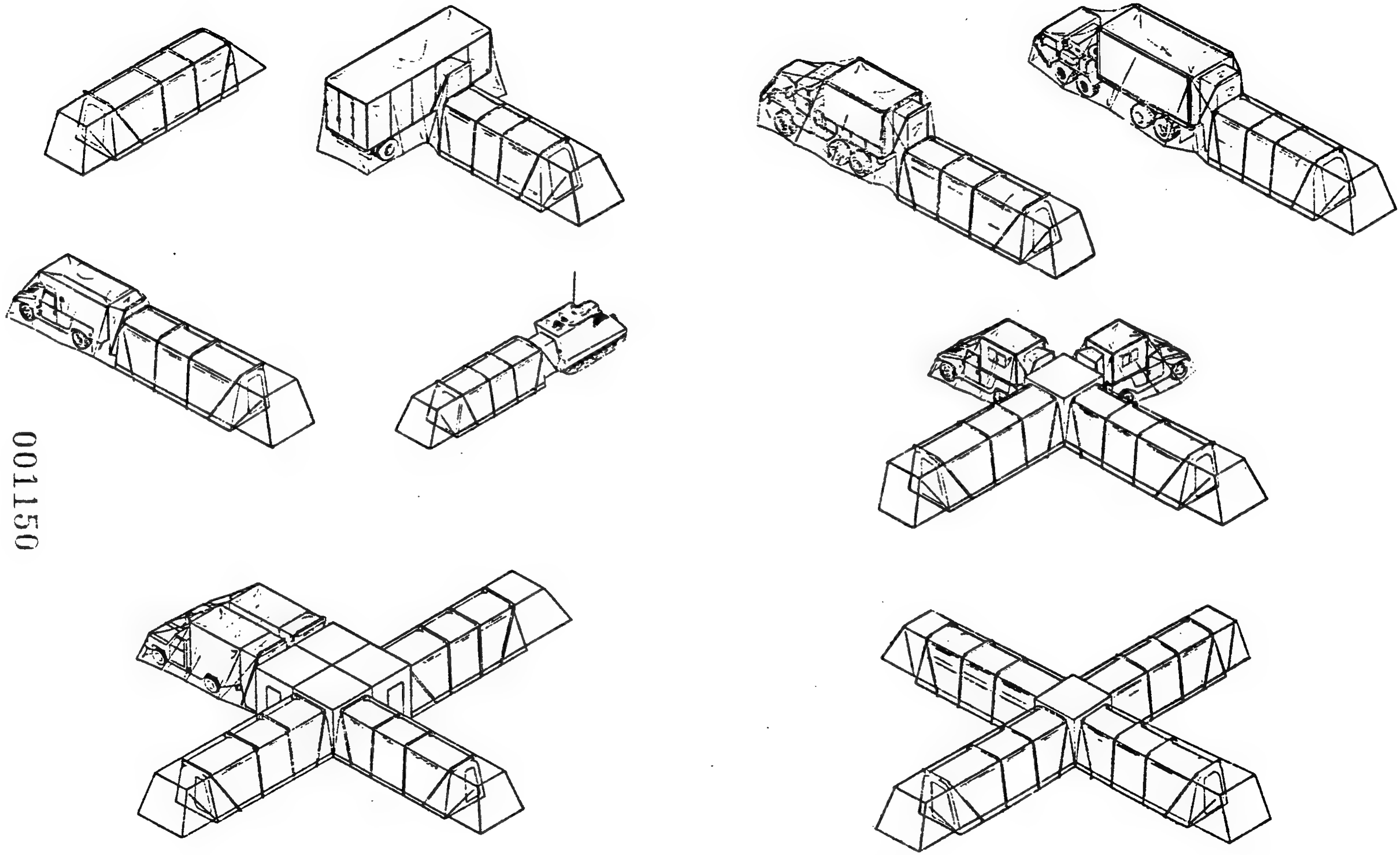

Figure 6. DEPLOYMENT CONFIGURATIONS

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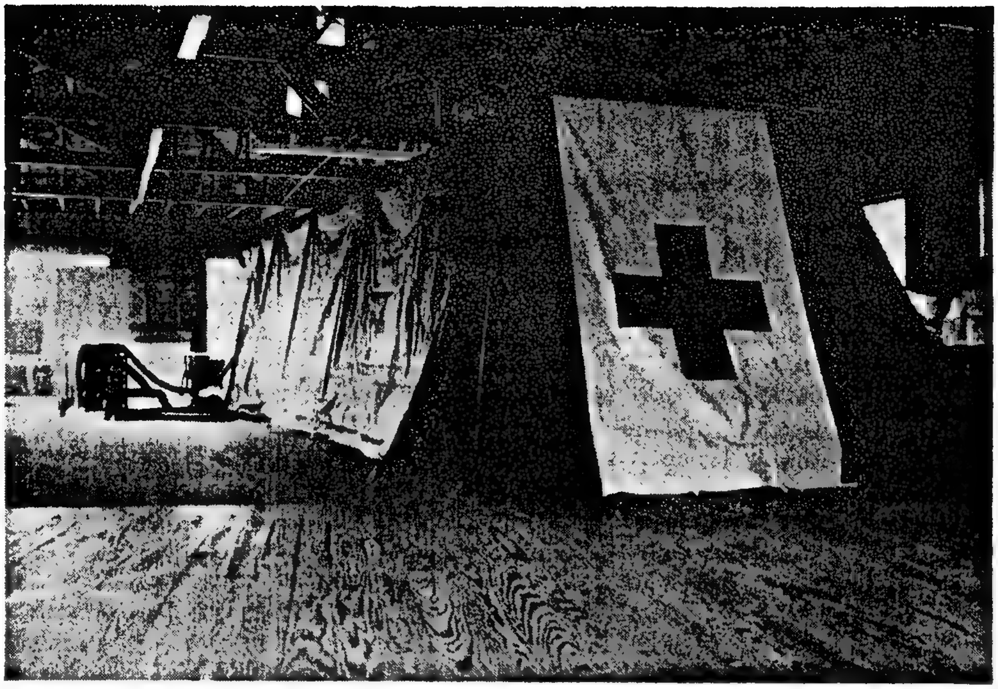
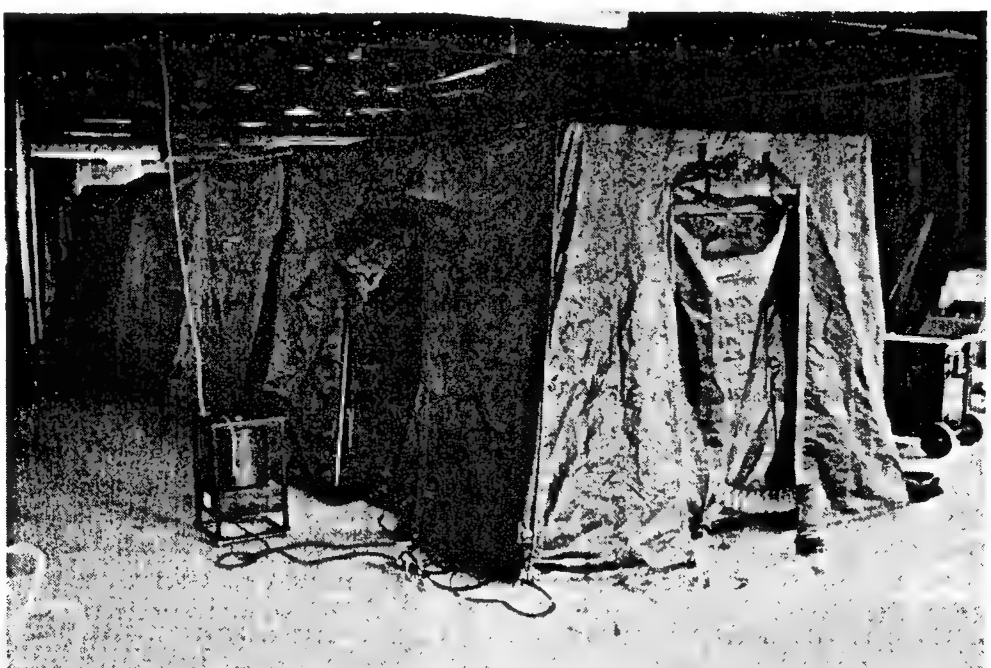
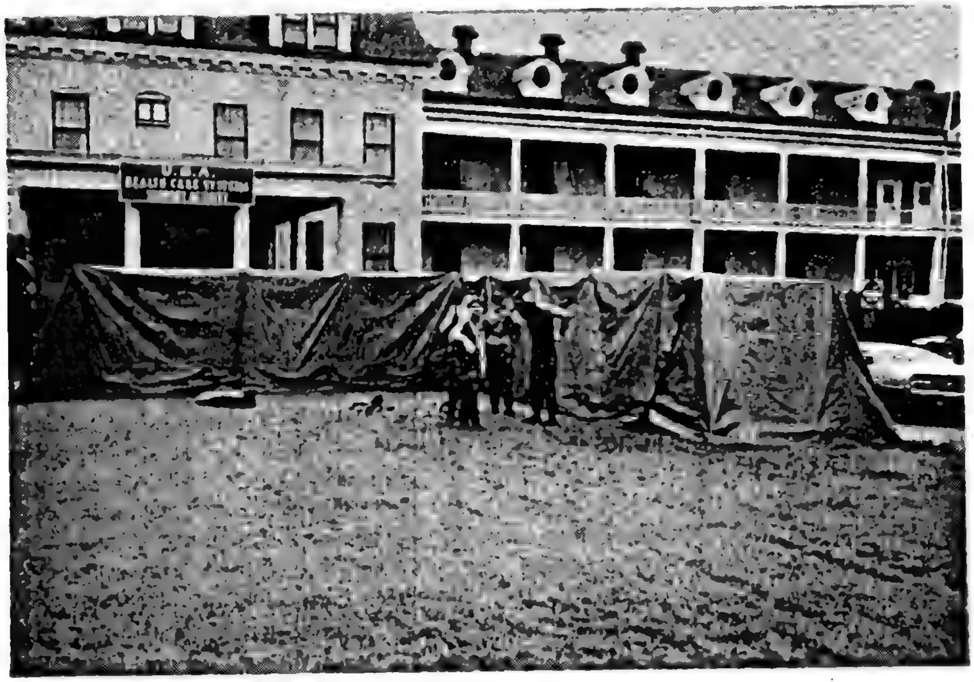
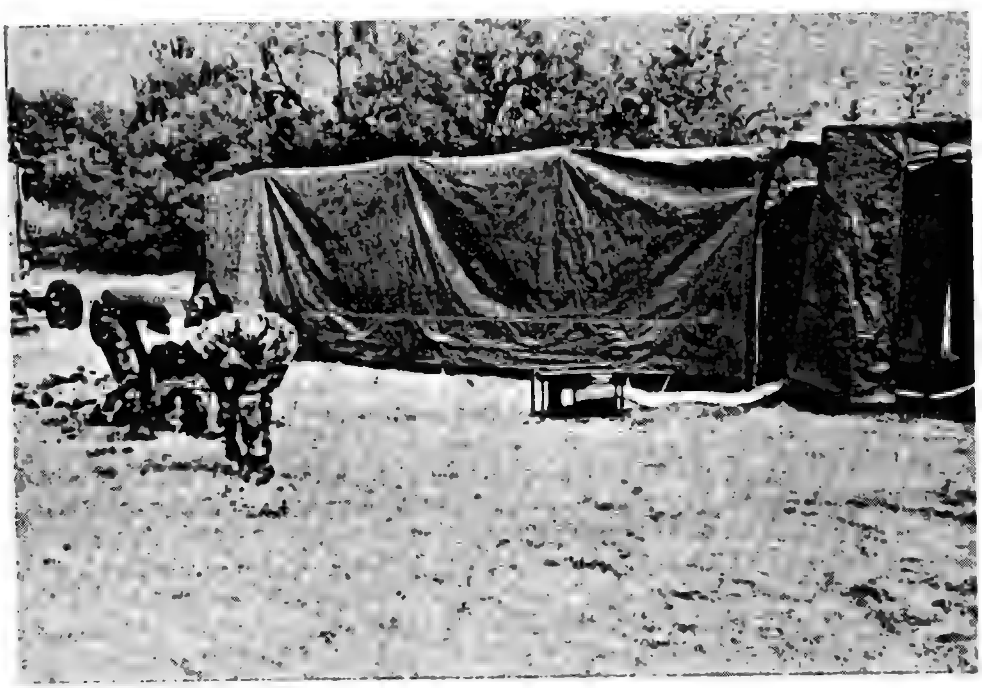




MPM ATTACHED TO IPE/T BTM -- INTERIOR DEPLOYMENT CONFIGURATION

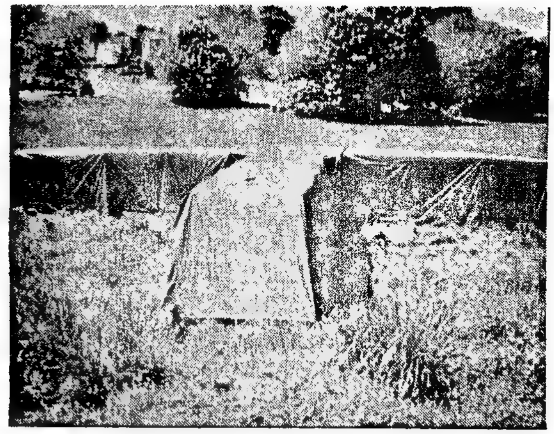


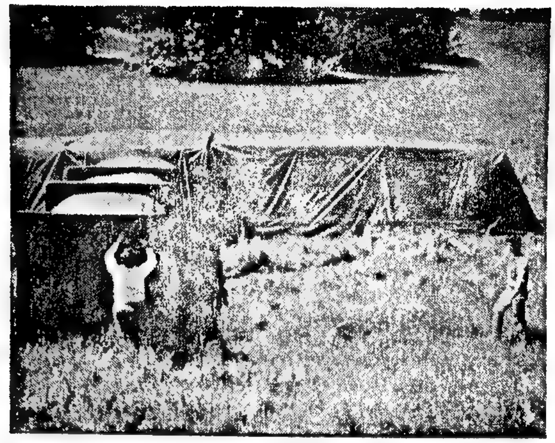
Two Externally Deployed BTMs Complexed with MPM at Ft. Sam Houston, TX



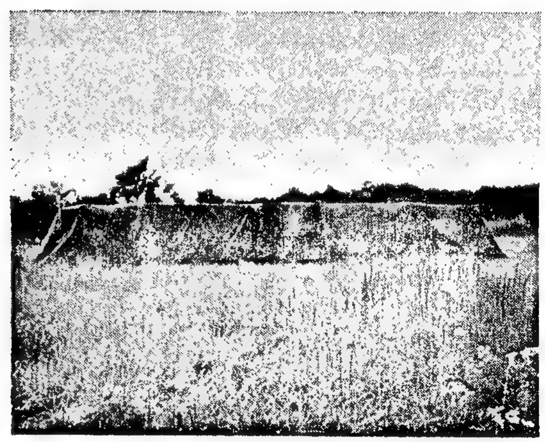
Two Externally Deployed BTMs Complexed with MPM at Electronics Security Command
Kelly AFB, TX

Triplex Configuration Using MPM





Duplex Configuration Using MPM



Inside View of Duplex Configuration

COMPLEXING CONFIGURATIONS USING MPM

CONCLUDING REMARKS - SAT, 17 MAY 1986

"Securing Installations Against Car - Bomb Attack"

William F. Pugh, P.E.

I appreciate the opportunity to make the concluding remarks to this comprehensive conference. It is an enviable position since I don't have to present any original material.

I want to thank each speaker for they have done an excellent job. I would also like to compliment each speaker for not being too commercial in their presentation. However, as the last speaker, I have the advantage of being able to break that precedent and will give a commercial. It's for SAME the Society of American Military Engineers. We have supported this conference and will support future conferences of this type. SAME is dedicated to a Strong National Defense and offers non-military engineers, as well as those in the military or employed by DOD agencies to contribute to the goal of strengthening our Nation. Please visit our booth and pick up information about our Society.

We all owe Mike Davis a note of thanks for bringing such a diverse group together to tackle a very difficult problem. I feel the conference has been very successful and that it has certainly exceeded my expectations! This success is directly attributable to the diversity of the group attending this conference. It would be interesting to see what the actual mix is: Would you please stand in turn.

(1) Security Service Consultants
(2) Architects and Consulting Engineers
(3) Security Systems Manufacturers
(4) Research Laboratories
(5) Construction Representatives of Using Agencies - Corps of Engineers, etc.
(6) Other

This Conference has given us each a unique opportunity to gain insite into many areas. Among them were:

(1) The threat which our facilities now face.
(2) Potential future threats.
(3) Development and testing of new equipment and technology to counter these threats.

(4) DOD and State Department Approaches to enhancing the physical security of their facilities.
(5) An analysis of historical defense systems and their application to modern security designs.
(6) Anti terrorist measures taken in Northern Ireland and Israel.
(7) Systematic design approaches for securing and hardening facilities.
(8) Various methods and problems related to access control.

We have also had an opportunity to learn several lessons. Some which come to mind are:

(1) If a potential enemy really wants to get us, he probably will. We must therefore make his efforts as difficult as possible and in such a way as to minimize damage all within economic constraints.

(2) The threats we are now trying to counter will undoubtedly change. Therefore, we must incorporate balanced protection with built-in flexibility for future hardening measures. This will certainly require innovation particularly within economic constraints.

(3) No single approach can be universally applied to all facilities. The design of each site is unique and should be approached as such. Beware of "cook book" designs.

(4) Our knowledge of hardening and securing facilities is incomplete. However, we have come a long way.

Finally, to become truly effective we must exert a concerted cooperative effort between all groups represented in this Conference. Research labs, both academic and military, must coordinate their efforts and must disseminate the results. Construction agencies must be aware that End users, A/E firms, Security Consultants and Manufacturers must all be included in design teams. Only in this way can balanced designs be truly effective in offering maximum protection at realistic funding levels.

In closing I again want to thank Mike; both as a representative of SAME but also as a practicing engineer; for sponsoring this highly successful Conference.

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of the Conference

"Securing Installations Against Car-Bomb Attack"

- The list is divided alphabetically first by affiliation, and subdivided by location and by attendees' names.

- Separate lists have been compiled for
  - the speakers,
  - the manufacturers,
  - and attendees from foreign countries.

- They are attached to the attendees roster.

- 176 attendees are not shown on this list.

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